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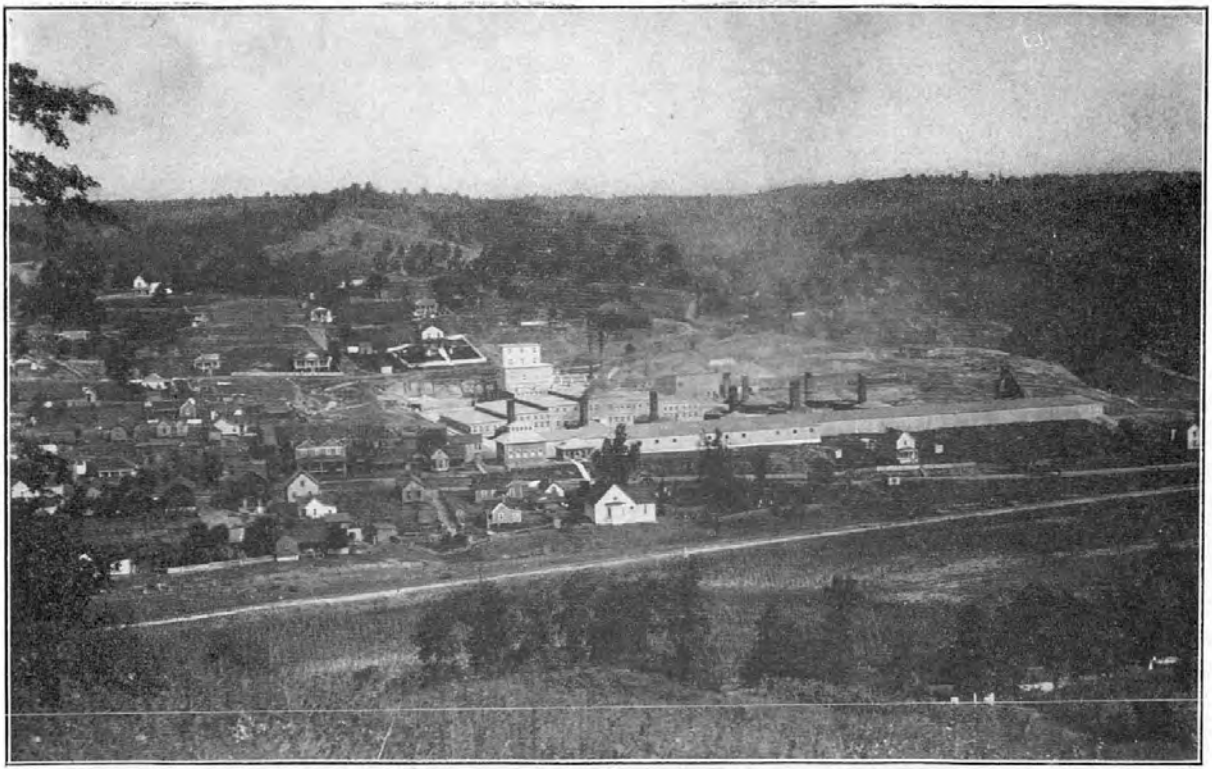

General view of Harbison-Walker Refractories Company plant, Olive Hill.

The
CLAY DEPOSITS *of* KENTUCKY

An Economic Consideration of the Pottery, Brick, and Tile Clays, Fire Clays, and Shales of Kentucky, With Notes on their Industrial Development.

BY
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ITHICA

Illustrated with Sixty-three Photographs, Maps and Diagrams

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Letter of Transmission

DR. W. R. JILLSON,
State Geologist,
The Kentucky Geological Survey,
Frankfort, Ky.

DEAR SIR:

I beg to transmit herewith my report on the Clay deposits of Kentucky, which is based on field work carried on during the summer of 1921 and laboratory work in the autumn following.

While neither time nor funds were available to make either the field or laboratory work as complete as desirable, still it is felt that the results given will serve to give a fairly clear conception of the clay resources of the state, and also indicate in what regions further search should be made. To the data collected I have added such other previously published information as it seemed desirable to incorporate. The arrangement of the report has been made in accordance with your suggestions.

Throughout the field and laboratory work I have been most efficiently and conscientiously assisted by Mr. Floyd Hodson, whose services deserve special acknowledgment. Mr. C. E. Bales also rendered considerable assistance during a portion of the field season. It is likewise proper at this time to acknowledge the many courtesies that we received from the clay working firms and their representatives in all parts of the state, and to Prof. A. M. Miller of the University of Kentucky.

Respectfully submitted,

H. RIES,

Cornell University,
Dept. of Geology,
Ithaca, N. Y.,
Nov. 19, 1921.

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Clay Deposits *of* Kentucky

CHAPTER I.

CLAY BEARING FORMATIONS IN KENTUCKY

Before taking up the clay and shale deposits in the different parts of the state it may be well to note briefly which of the geological formations found in Kentucky are likely to contain materials of value to the manufacturer of clay products. Additional data on their general distribution can be obtained by reference to the geological map of Kentucky and a number of the special or regional reports issued by the Kentucky Geological Survey which are listed in the appended bibliography.

From what follows it will be noted that there are a number of clay or shale-bearing formations but that all do not occur in sufficient thickness to be workable, nor are all of them of the proper character. However, even without these there remain a number of deposits of commercial value, which can be used to produce a variety of clay products.

The formations noted below are referred to in the order of ascending geological age.

Eden Shale. The Eden formation of the Ordovician (Ref. 22) was named from Eden Park in Cincinnati, Ohio, and there consists largely of shale with some interbedded limestone layers. On account of the nature of the shale it is sometimes called "blue clay" and "soapstone."

Because of the predominance of shaly beds at Cincinnati the Eden shale formation has been used there for brick manufacture, but as it extends southward into Kentucky the limestone layers increase and the shale layers decrease so that while it underlies a considerable area within the state, it is of no value to the clay worker in its fresh condition. It forms a belt of hilly country from 5 to 15 miles wide which has to be traversed in passing from the outer margin of the Bluegrass region to the inner part of that district.

Plum Creek Shale. This lies near the base of the Silurian system of rocks, and is named from its occurrence on a creek in Madison County. It might do for the manufacture of clay

products if it were thicker, but it is nowhere over 5 feet. (Ref. 22.)

Osgood Shale. This formation is a subdivision of the Niagara series of the Silurian system of rocks, which includes several shale formations that are prominent on the east side of the Cincinnati arch but which do not appear to have been subdivided on the west side.

The subdivisions on the east side of the Bluegrass region include the Estill and Lulbegrud shales mentioned below.

In Jefferson County (Ref. 2, p. 78) the Osgood formation contains a shale 15 to 20 feet thick which lies between limestones. It is mostly a coarse, lumpy, gray shale running high in lime and magnesium carbonates. It weathers to a clay which forms white banks beneath the limestone beds.

It is probably of little commercial value as better shales occur in abundance in the general area in which it is found.

Lulbegrud Shale. This shale is named from Lulbegrud Creek, on the boundary of Clark and Powell counties. (Ref. 11.)

It rests on the Oldham limestone, and underlies the Estill shale, being sometimes separated from it by the Waco limestone, which is of great aid in distinguishing the two shales in the field as they resemble each other very closely.

The Lulbegrud which outcrops around the Bluegrass region is a light, smooth, bluish-gray shale which weathers somewhat readily to a very plastic clay. The chief impurities in it seem to be scattered crystals and rosettes of gypsum that can be seen lying on the weathered surface.

It is a good material for the manufacture of brick and tile, but does not form a deep deposit, being rarely over 15 feet thick. However, on account of its close association with the Estill shale it could often be worked in connection with it.

The Lulbegrud shale can be seen at a number of different points. There are excellent exposures along the tributaries of Lulbegrud Creek in Clark and Powell counties. Other outcrops are found south of Bardstown, Nelson County; in the lower part of the barren hills known as Knob Licks north of Olympia, Bath County; in the territory between Irvine, Clay City, Indiana Fields and Brassfield, in Estill and Powell counties, where it is 13 feet thick; at Abner's Mill, Powell county; near Vienna

on the Red River, Powell County; 1 mile east of College Hill, Madison County; just north of Waco, Madison County; east of Panola, Madison County, between the wagon road and railroad; southeast of Brassfield, Madison County; 3 miles slightly north of east of Bobtown, Madison County; 1½ miles south of east of Bobtown, Madison; and 2 miles northeast of Berea, Madison County.

The Waco limestone which lies above the Lulbegrud occassionally contains shale layers, but they cannot be commercially separated from the limestone.

Estill Shale. This is a light, bluish gray, smooth shale, which may be gpysiferous, but not so much so as the Lulbegrud. It may reach a maximum thickness of 100 or more feet and is well worthy of consideration by the manufacturer of brick and tile. While it is overlain stratigraphically by the Onondaga limestone, it is not difficult to find exposures of it where the overburden is limited. The material weathers easily to a very plastic clay.

It works up to a very plastic mass and fires to a red body which should prove of value for the manufacture of brick, tile, and hollow blocks. (See Chapter V.)

Excellent exposures of this shale may be seen on the Irvine-Winchester Branch of the Louisville and Nashville Railway east of Howard Creek, the type exposures being around Irvine. (Ref 11.) Other good ones can be seen just north of Crab Orchard, where along the pike to Lancaster, a continuous section of shale 65 feet thick is exposed on the west side of the road. Further north in Lewis and Fleming counties even thicker sections of the bluish-white clay are seen.

Waldron Shale. This is also of Silurian age, and forms deposits up to 15 feet in thickness. It is not found on the east side of Bluegrass region. The material is high in lime and magnesium carbonates. It weathers easily to a greenish clay. In Jefferson County, for example, where it occurs, (Ref. 2, p. 84) other and better shales can be found.

Ohio, New Albany and Sunbury Shales. These are black shales which are quite extensively developed in certain parts of Kentucky and easily recognizable. The first two are of Devonian age, while the third is of Waverly age or higher up geologically.

Roughly speaking they occur chiefly in a curved belt of territory, lying inside of that outlined for the New Providence shale. (Fig. 1.) So far as the clay worker is concerned there is not much use of separating them as they are all gritty and black fissile shales, which weather first to flaky particles, that lack plasticity when ground and mixed with water. On complete weathering they loose their carbonaceous matter and change to a sandy reddish clay which can be used in the manufacture of bricks.

In their unweathered condition it is better not to use them and in place to select the New Providence, or Estill shales.

Bedford Shale. This is an important formation to the clay worker in Ohio, because in the central and northern portion of that state it contains a considerable quantity of good shale. (Ref. 11.) When the formation extends southwest into Kentucky it may contain considerable sandstone, and the shale beds become more gritty. Geologically the Bedford shale underlies the Berea sandstone formation which in Kentucky shows a splendid development of ripple marks, so that it can be easily identified. However as the Berea is traced southward in Kentucky it also changes into shale.

In Lewis County the Bedford shale is 95 feet thick. According to Foerste at Petersville, Lewis County, the combined Berea and Bedford formations consist of sandy shale with limestone layers. In the hills, a half mile to the east of Olympia springs, there is 12½ feet of soft bluish shale, changing to sandy shale in places. In the Caney Switch area of Bath County there are 19½ feet of Bedford-Berea shales. These represent the most promising localities for these shales in central Kentucky.

New Providence Shale. This is a very important, widely distributed shale formation, of Mississippian age, whose excellent character has already received recognition by the clay worker, and which is being worked at several localities in Kentucky.

It occupies a curved area, practically coextensive with the Waverly formations, extending in a great curve from Jefferson County on the west southward and eastward through Taylor and Lincoln County and then northeastward to Fire Brick in Greenup County.

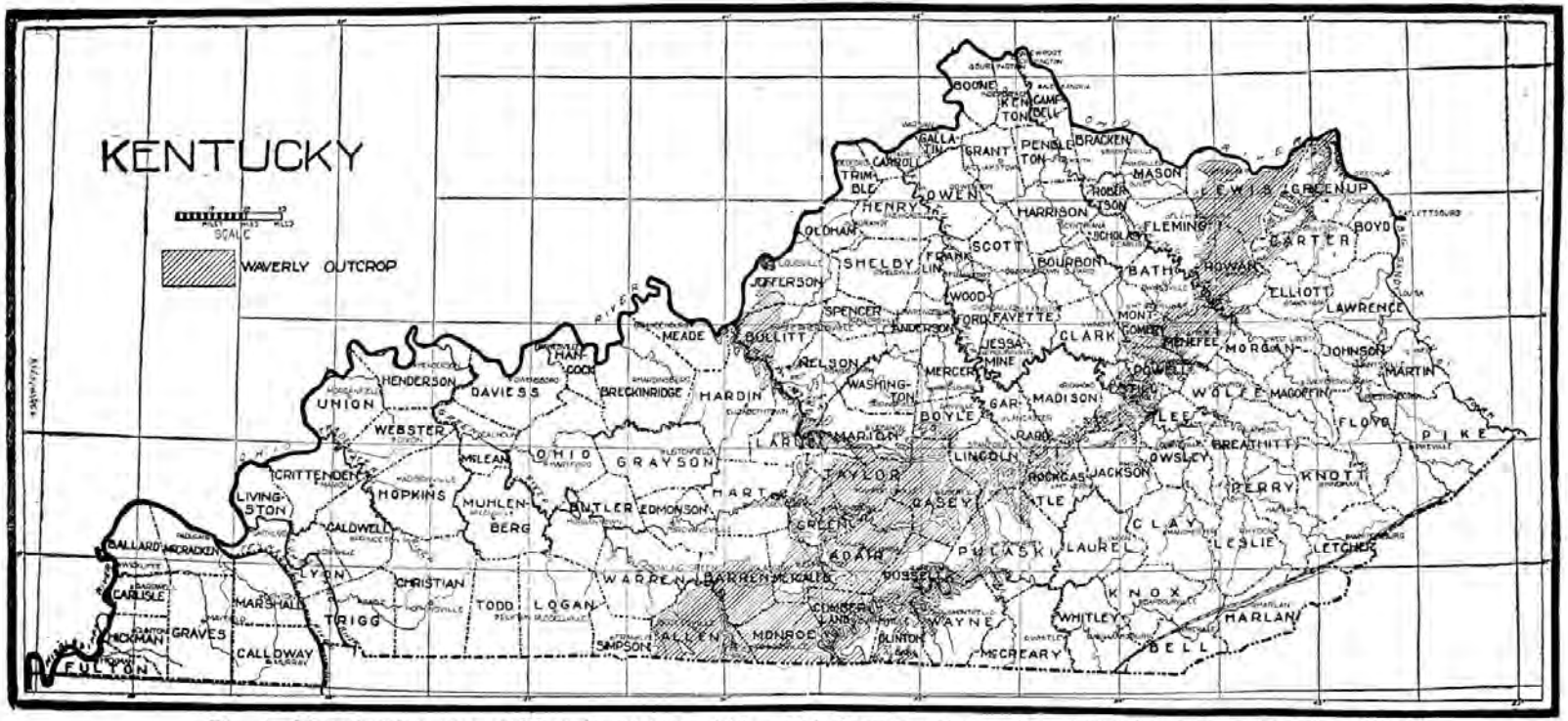

Fig. 1. Map showing area of Waverly outcrop within which New Providence shale formation may occur (after Miller).

This formation has also been referred to as the Linietta, and Raccoon. It corresponds to part of what is known as the Cuyahoga shale in Ohio, and is used for clay products in that state.

The New Providence shale is a soft, usually greenish shale, which weathers rather easily to a plastic clay. But even the fresh shale grinds up without difficulty, and forms a plastic mass with water.

In Jefferson County, where outcrops of it are well located for working, it has a thickness of 150 feet, though the entire section is not always exposed. Deposits of considerable size are said to occur near Chicago, Marion County. Just west of Junction City, Boyle County, the exposures in Blue Knob show a thickness of about 80 feet, and here where it rests on the black Ohio shale it shows near its base numerous concretions of phosphate. South of Central Kentucky the shale becomes more calcareous, and in Southern Kentucky passes into a limestone.

East of the Bluegrass region it lies within the belt of hills called the Knobs, and is less favorably located for working.

At Firebrick on the Ohio River a thickness of at least 75 feet occurs in the hills and is also easily accessible.

In Jefferson County the upper half of the formation at times contains rather abundant iron carbonate concretions which may be coated with gypsum, and similar concretions have been noted at other points. These concretions may range from the size of a marble up to a foot in diameter.

A chemical analysis of this shale from Coral Ridge, Jefferson County. (Ref. 2), gave:

Silica	60.40
Alumina	19.73
Ferric oxide	4.72
Lime	.78
Magnesia	2.10
Soda	.96
Potash	4.87
Titanic oxide	.83
Ignition	5.96
Moisture	.60
	99.95

The New Providence is the most widely utilized shale in Kentucky.

It is quarried at Coral Ridge south of Louisville, Jefferson County, for making building brick, hollow blocks, and common red earthenware. It is also worked at Firebrick, Lewis County, for making paving brick.

Some years ago brick were made from it about six miles southwest of Louisville, but the plant has gone out of existence and the shale was worked up at a factory erected for making potash. This, too, is no longer in operation, but at the locality there is a shale bank fully 75 feet high, well located for easy working and only a few hundred feet from the Illinois Central Railway.

Rosewood Shale. This formation overlies the New Providence stratigraphically, although between the two there is a sandstone and conglomerate.

Butts, (Ref. 2, p. 150), states that it forms the main body of the knobs south of Louisville, where it forms most of the slopes of these hills. Southward in Bullitt County it slopes downward until at West Point its top is almost at the level of the railroad.

The entire formation is exposed in the road west from Brooks, Jefferson County, which is 2½ miles southeast of Coral Ridge. It can also be seen along the road descending from Jefferson Hill to Bear Camp Run, where it is about 190 feet thick. There are also said to be limitless quantities of it along the Louisville, Henderson and St. Louis Railroad between Kathryn Station and the north side of Moremens Hill.

Parts of it at least contain a considerable quantity of iron carbonate concretions.

It is not quite as good as the New Providence shale, but has good plasticity and fires to a red color. It could be used for bricks and hollow blocks. (See Chap. V.)

Chester Series. The Chester series of the Mississippian is made up of sandstones, shale and limestones which in western Kentucky have an aggregate thickness of 600-800 feet.

In western Kentucky these rocks surround the coal field in a belt 5 to 10 miles wide, (Fig. 2), the area of outcrop lying between the Mammoth Cave limestone belt on the south and east, and the coal measures rocks of the Pennsylvanian.

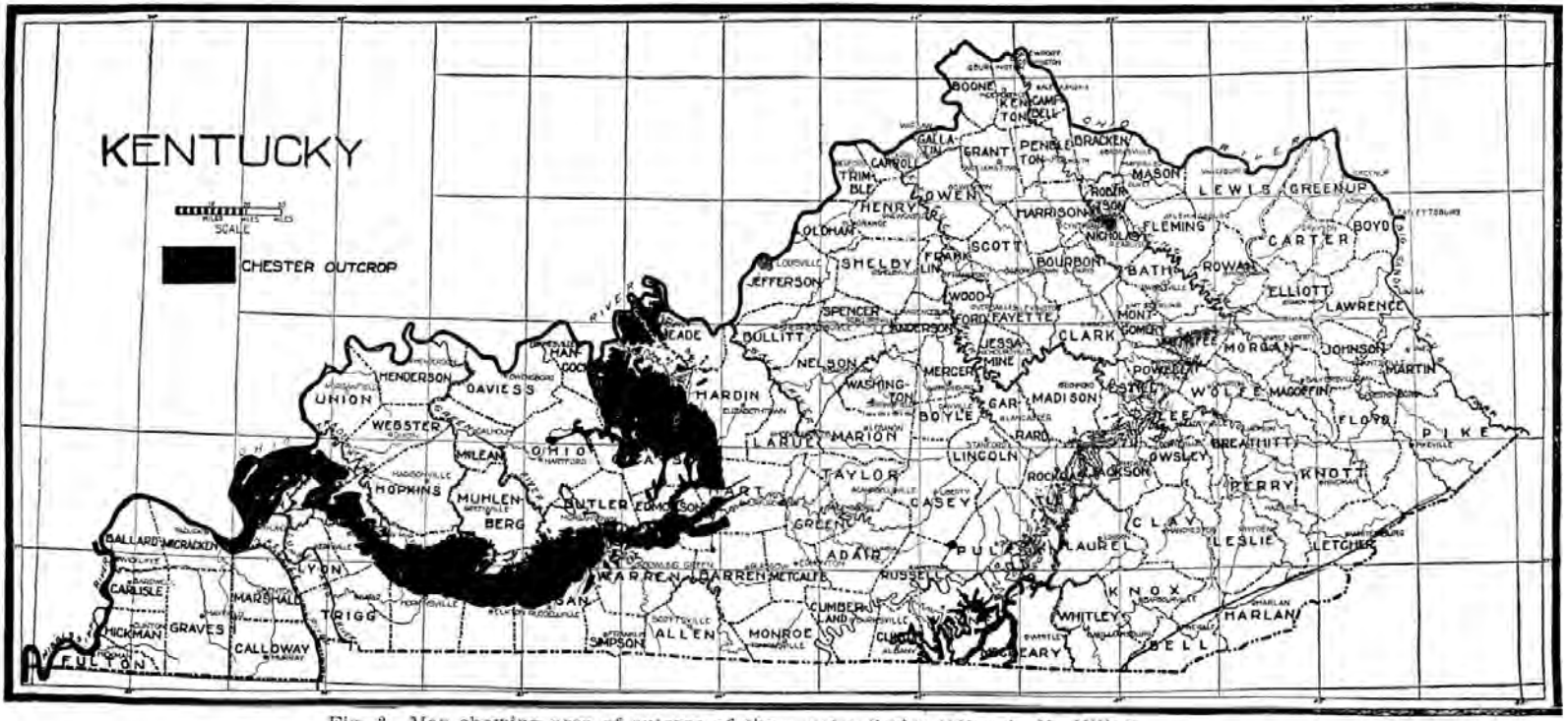

Fig. 2. Map showing area of outcrop of the Chester Series (after A. M. Miller).

Since the last named are the youngest of the three series mentioned the Chester rocks at all points dip inward towards the center of the western coalfield. The Chester belt of outcrop is marked by poor agricultural land, which is in strong contrast to that underlain by the good soil of the Mammoth Cave limestone belt. A line connecting Russellville, Elkton, Hopkinsville and Princeton lies approximately along the southern border of the Chester formations. The Chester sections on the eastern and western sides of the western coalfield are not identical, in fact that on the eastern side is appreciably thinner than that on the western but it contains the following deposits of shale that are well worthy of investigation.

Ridenhower Shale. This is a soft bluish gray shale, which weathers to a bluish or greenish clay, that may contain some layers of calcareous sandstone or sandy limestone. (Ref. 3, p. 74.)

Stratigraphically it lies between two sandstones known as the Bethel and Cypress or Big Clifty, and its full thickness is 50 feet. As it weathers rather easily fresh sections are difficult to find, however. Butts notes one on the road to Siloam school at a point 3 miles west-southwest of Marion, Crittenden County. Here the full thickness of 50 feet or so is exposed in the ditch with the sandstones above and below. Butts says that while exposures of the fresh shale are rare its presence is almost everywhere indicated in the topography by a shallow depression of the land surface between the two sandstones that lie respectively above and below it.

On the eastern side of the coalfield in Hart and Hardin counties there are some clays underlying the Big Clifty sandstone which may represent the Ridenhower shale.

Buffalo Wallow Shales. On the eastern side of the western coalfield, from Breckenridge to Warren counties the subdivisions of the upper part of Chester formation from the Tar Springs sandstone upward are not as clearly divisible, and these are referred to collectively as the Buffalo Wallow formation, the name being derived from Buffalo Wallow, a cirque-like depression in these shales which is located on the highway 2 miles west of Cloverport, Kentucky.

The Buffalo Wallow formation is made up chiefly of beds of soft bluish shale, but includes also red shale, together with some sandstone and limestone. It is a formation that should be prospected by clay workers for it seems capable of yielding a supply of red-burning clays of excellent character.

At present it is worked only at Cloverport, Breckinridge County, where a beautiful red floor tile and roofing tile are manufactured from it.

The Buffalo Wallow formation is overlain unconformably by the Pottsville conglomerate, but before this was deposited there was an interval during which the land surface was considerably eroded so that the Pottsville does not everywhere rest on the same division of the Buffalo Wallow formation, indeed to the south the Pottsville rests almost directly on the Mammoth Cave limestones which are below the Buffalo Wallow.

Of considerable scientific interest, but of no probable commercial importance, is the so-called kaolin, which is found in the Buffalo Wallow formation just below the Pottsville in Hart, Hardin, Taylor and other counties.

This material when pure and fresh consists of pockety masses of white clay, sometimes soft and powdery, at other times fairly hard, dense and resembling unglazed porcelain. It is identical with the Indianaite found immediately under the Pottsville in Lawrence and other counties of Indiana. In the latter state however the material occurs in much larger quantities than it does in Kentucky. At one place in the latter state bauxite and Wavellite have been found in small quantities associated with it, and this is the only locality in Kentucky where any bauxite has been noted.

Chester Shales of Eastern Kentucky. The Chester occurs along the western border of the eastern coalfield, (Fig. 2), but is much thinner, probably not over 100 feet thick. It consists of both sandstones and shales. The outcrops are in a hilly region rather remote usually from lines of transportation and little is known regarding them.

Pennsylvanian. The Pottsville, Allegheny, Conemaugh and Monongahela series of the Pennsylvanian are all recognized in Kentucky.

The Pottsville or lower division of the Pennsylvanian consists chiefly of conglomerate or pebbly sandstone. It is found around the western coal field, and there is divisible into two parts, (Ref. 23, p. 154), with about 100 feet of shales separating them. Detailed information is not available regarding these shales, but those worked at Hawesville and Lampkin, Hancock County, are probably of this age.

In the eastern coal field the Pottsville carries one important deposit of fire clays in Boyd, Carter, Rowan and Elliott counties, and this is being worked at a number of points. Above this fire clay there is an impure clay known as the huckleberry clay which may be available for pottery purposes.

The formations of the Allegheny series are found in the eastern and western coalfields of Kentucky, and consist of shales, clays, sandstones, coals and some limestones.

The shales may vary in their character, some being hard and gritty, others moderately soft and argillaceous. Not a few are too carbonaceous to be utilized in the manufacture of clay products.

The best types are those which are argillaceous and relatively free from carbonaceous matter.

Western Coalfield. Little use has been made of the Allegheny shales in this area, except at Madisonville where the soft and somewhat weathered shale is used in the manufacture of brick and tile. Tests made on other samples from this vicinity indicate that they can be used in addition for hollow blocks and probably stoneware. Some of the coals as shown in Chapter IV are underlain by shales of plastic and red-burning character, but thus far practically no refractory clays have been found in the western coalfield.

Eastern Coalfield. The most important clay or shale deposit in the Allegheny series of the eastern coalfield is a bed of plastic fire clay, which occurs at the horizon of the Ferriferous or Vanport limestone, in parts of Carter and Boyd counties. It is not as refractory as the flint and semihard clay found in the Pottsville, but is entirely satisfactory for use in fire brick mixtures. It at times contains lenses of flint clay. One objection to the material is that it apparently does not always show refrac-

tory qualities over large areas. In other words the fire clay may grade into nonrefractory material.

This clay is worked at Hitchins and Denton, Carter County, and at Ashland, Boyd County. Mines have been opened at other localities but they are idle at the present time.

A widely distributed flint clay is found associated with what is known as the Upper Mercer, No. 4, or Fire clay coal. It forms a most persistent parting in this coal bed, but is never over a few inches in thickness, and hence where found is of no commercial value.

The Allegheny series may also carry shales, some of which as those tested from between Olive Hill and Grayson in Carter County or from Torchlight in Lawrence County make an excellent buff brick.

Miller states that in the eastern coalfield the Conemaugh division of the Pennsylvanian forms the surface formation in parts of eastern Lawrence and Boyd counties, and there contains a prevalence of red and purple shales, some of which might be suited for the manufacture of clay products.

Tertiary. Clays of undoubted Tertiary age are found in the Purchase region of Kentucky. Most of these occur as lenses in the Lagrange formation and are actively worked to supply ball, and sagger clays for use in the manufacture of white pottery ware, electrical porcelain, wall and floor tile, glass refractories, etc. Some are worked near Pottertown, in Calloway County, and Bell City, Graves County, for stoneware manufacture. The Porters Creek formation of the Tertiary is worked at Briensburg, Marshall County, to supply stoneware clays.

The most important developments are the clay pits at Pryorsburg, south of Mayfield, Graves County, worked since 1891, and a number of smaller operations clustered to the west of Hickory and Viola, in the district north of Mayfield. These two groups of pits supply clays of the ball and sagger type.

Several other pits are operated at Wickliffe, Ballard County.

In addition to the Purchase clays there are a number of isolated deposits of stoneware clay belonging to the Irvine formation which is also regarded as Tertiary in age. These are

worked around Waco and Bybee in Madison County, and used for stoneware and blue art pottery.

Pleistocene. In addition to the surface loams of the Columbian formation which are abundant in the Purchase region this includes a number of clay deposits of alluvial character found underlying terraces along the rivers. The most extensive are those along the Ohio River, but additional ones occur along the Licking, Tradewater, Green, and other streams. They represent a widely used source of material for many brick and tile plants. Among them are to be included those at Paducah, Maysville, Sturgis, West Point, Ashbyburg, Henderson, etc.

Residual Clays. Geologically these are of very recent age, although they may have been formed by the weathering of rock formations of different ages. Such clays are derived from the decay of either shales of limestones, the sandstones not yielding this material unless they are very clayey or feldspathic.

Clays of the residual type are to be found in practically all parts of the state. They are all ferruginous and hence burn to a red color. In regions where there is nothing but limestone they are the only source of plastic material available to the clay worker. They have been utilized for brick manufacture at Whitner southeast of Louisville, Jefferson County; at Lexington, Fayette County, and at Nicholasville, Jessamine County. All of these have been formed by the weathering of limestone.

The product made from them is usually common brick.

CHAPTER II.

TESTS AND THEIR INTERPRETATION

The investigation of a clay in the laboratory may include both chemical analyses and physical tests.

If a clay is to be used in the manufacture of burned clay products, chemical analyses are rarely of any value because they show practically nothing regarding its physical characters. If it were known that all the substances shown by the chemical analysis were uniformly distributed through the clay and intimately blended, then it might be safe to make some deductions regarding such properties as the fusibility, and color-burning qualities, but in the absence of evidence, interpretations are not always safe.

Perhaps one of the safest deductions to make, is that regarding a positive refractory character. That is to say, if a clay contains a low total content of fluxing impurities it may be regarded as a fire clay.

The physical properties, which are all-important in the use of a clay, must be determined separately. These properties include plasticity, water of plasticity, shrinkage, fineness, transverse strength, bonding strength, slaking test, vitrification, color after firing, and fusion.

Plasticity

This is the property by virtue of which a wet clay can be molded into any desired shape, which shape it retains when dry. There is no satisfactory means thus far known for accurately measuring the plasticity. With experience a person can tell the different degrees of plasticity, and express them by such terms as high, good, fair and low. Excessive plasticity may be as undesirable sometimes, as a deficiency of this property. It can be reduced by the addition of non-plastic material such as sand. If a clay is deficient in plasticity it may crack in the molding, or at times be difficult to form, especially with machinery. Excessive plasticity is liable to cause high shrinkage, accompanied by warping and cracking.

Water of Plasticity

In order to render a clay plastic it is necessary to add a certain amount of water, the quantity to be added varying with different clays. Clays of high plasticity in general require a high percentage of water, while clays of low plasticity or lean ones take the minimum quantity of water. It is also found that the amount needed is not always a fixed quantity, but for some clays may vary between rather wide limits, this being especially true of highly plastic clays.

A simple method for determining this consists in weighing a lump of the clay that has been worked up with water, drying it thoroughly in an air bath at 110°C. and weighing again. The per cent of water lost is calculated in terms of the weight of dry clay. This gives the water of plasticity.

Shrinkage

After a clay has been worked up with water to a plastic mass, and is set aside to dry the water begins to evaporate, and during this process the particles of the clay draw closer together until they are in contact. The shrinkage thus produced is called the air shrinkage. Even after it ceases there may still be water in the spaces between the clay grains and this can only be driven out by heating to constant weight at 110°C. This latter is the pore water. That lost during air shrinkage is the shrinkage matter. The sum of the two is the matter of plasticity.

Clays of high plasticity, usually show a high air shrinkage, on account of their high water-of-plasticity content. Lean clays show a low air shrinkage.

Excessive air shrinkage is undesirable as it is lkely to be accompaned by warping and cracking of the clay.

The air shrinkage may be expressed in terms of length or volume of the test piece. If the former it is stated in percentage terms of the length of the test piece as molded. If the latter, it is expressed in percentage terms of the dry volume. Since the linear shrinkage when measured on different sides of a test brick, or in different directions, is not always exactly the same, it is sometimes considered best for accurate work to determine the volume shrinkage.

When the clay is fired it undergoes an additional decrease in size known as the fire shrinkage, and this reaches its maximum when the clay reaches a condition of maximum density. Beyond this the fire shrinkage decreases due to swelling of the clay.

The fire shrinkage may also be expressed as linear or by volume, the latter in terms of the dried clay.

Fineness

When making a complete test of high-grade clays the fineness of the material is sometimes determined. The larger-sized particles may be separated by means of sieves, but the smaller ones can be separated by some method of elutriation or washing.

The fineness may affect the different physical properties

Transverse Strength

The transverse strength of a clay is determined by shaping it in bars 1 inch square and 8 inches long. These are thoroughly and carefully dried, and then broken by placing them on supports 6 inches apart, and applying a load on top of the bar at a point midway between the supports. As the bars vary some in their cross section after drying, it is necessary to express their strength in some unit term which is known as the modulus of rupture.

This is calculated from the formula:

$R = \frac{3\ w\ l}{2\ b\ h^2}$ in which

R—modulus of rupture

l—distance between supports

w—weight required to break the bar

b—width of bar

h—height of bar.

Clays of high plasticity usually show a good modulus of rupture. Good strength enables the clay also to stand rougher handling in its dried condition.

Bonding Strength

This is determined by making bars consisting of a mixture of equal parts of clay and standard sand. The transverse strength of these is tested as described above, and the effect of the addition of sand on the modulus of rupture noted.

The practical bearing of the test is this. The manufacturer of pottery, crucibles, glass pots and other wares may add 40 or more per cent of non-plastic material to his clay in order to reduce the shrinkage and tendency to warp and crack. If the clay is of high bonding power it may stand the addition of considerable non-plastic material without having its transverse strength reduced too low. Some clays show an increased strength with sand added. The test is chiefly of value in the case of refractory bond clays.

Slaking Test

This may be made by placing thoroughly dried one inch cubes of the clay in water and noting the time required for them to slake down completely. Strong clays require a longer time to slake than weak or lean ones.

Vitrification

This is carried out by firing test pieces slowly to successively higher temperatures. After each firing the porosity of the clay is determined. As the pores of the clay close up with progressing fusion the porosity decreases, and theoretically becomes zero when the point of maximum density is reached. Beyond this point the clays swells, and its porosity again increases. The point at which this change takes place indicates the beginning of overfiring.

In some clays the temperature interval between the attainment of a condition of maximum density or vitrification, and the temperature of overfiring is short, and such clays are said to have a short firing range. Highly calcareous clays show this.

In others the temperature interval between the two points mentioned is large, and the firing range is said to be long. Such clays are best adapted to the manufacture of vitrified wares.

Instead of determining the porosity it is easier and often customary to determine the absorption. It is not quite as accurate, but often sufficiently so for commercial purposes.

Color After Firing

This is always noted as it has an important bearing on the use to which a clay can be put. It is especially important to the manufacturer of whiteware who requires clays that will fire to a white body.

Hardness

The hardness of a clay after firing is usually determined by noting whether or not it can be scratched with a knife. If the point of a knife will not scratch it, the clay is said to be steel hard.

Fusion

The fusion point of a clay can be made by molding the material into small cones of standard size, and noting the temperature at which the clay has softened sufficiently so that it will bend over until the tip touches the base. Or it can be placed in the furnace with standard cones, and its fusion point be expressed in terms of these. The latter method especially is generally used for fire clays. The standard or Seger cones represent a series of mixtures whose theoretic fusion points cover a considerable range of temperature. They are not to be used for temperature measurements, since the fusion point is affected by the condition of the kiln atmosphere. They are, however, consistent with each other. The theoretic fusion points differ by intervals of 20°C. Thus cone 010= 950°C; cone 05= 1050°C; cone 1= 1150°C, and so on.

The Requisite Qualities of Clays for Different Purposes

Clays vary greatly in their physical properties, and it is upon this that their use for different purposes depends. Moreover let it be understood that the clay employed for a certain purpose may often show an appreciable range of certain characteristics, and furthermore that two different clays might when used alone be of little value for making a certain type of ware, but if mixed together would serve admirably, because of the blending of their physical properties.

The general characters of a clay required for the more important uses to which it can be put are given below.

Common Brick Clays

Almost any red-burning clay that is sufficiently plastic to mold can be used in the manufacture of brick, provided it does not show excessive shrinkage which would cause it to warp and crack in drying and burning, and also provided it fires to a hard body at a moderate temperature. It should also be free from pebbles or concretions, especially of carbonate of lime, as the latter after firing tend to air slake and swell, thus splitting the brick (Fig. 3). Sand is sometimes added to brick clays to

Fig. 3. Bricks split by lumps of limestone, changed to quicklime in firing.

reduce their shrinkage. If the clay contains pebbles or other stony material in large amounts these are sometimes removed by rolls, or crushed before the clay is fed to the machine. The clay should also burn steel hard or nearly so at a temperature of about 1000°C. Large lumps of gypsum are objectionable, but small pieces are not injurious.

Cream-burning calcareous clays may also be used for common brick if their other physical properties are satisfactory.

An absorption of over 15% after firing is usually undesirable.

Drain Tile Clays

Drain tile are manufactured from red-burning clays of good plasticity. The proper plasticity is necessary as they have to be molded in a stiff-mud machine. They should be free from coarse impurities, and fire to a steel hard body at a low temperature, as 1000° or 1050°C. without excessive shrinkage. The clays resemble common brick clays, but are usually smoother.

At some plants the same clay may be used for common brick and drain tile, or one part of the bank may be used for one, and another portion of the bank for the other, as it is not uncommon to find that the different beds in a clay or shale bank may vary somewhat in their shrinkage and plasticity.

Face Brick

Several types of clay are used for this purpose, as follows:

1. Red-burning clays, of proper plasticity, free both from coarse impurities or sufficient soluble salts to form a white scum. The color after firing should be a good red, and the brick should be steel hard. They may be fired at from 1000° to 1100°C. The same type of clay is also used for making rough-texture brick.

2. Low-grade fire clays which burn to a buff color, and otherwise have the same physical properties as the preceding type. Both grades should possess good transverse strength, showing a modulus of rupture preferably of at least 150 lbs., although it may run much higher.

3. Cream-burning calcareous clays. None of this type are used in Kentucky.

Paving Brick

These are commonly made of red-burning clays or shales possessing sufficient plasticity to mold well in a stiff-mud machine. They should have moderate air and fire shrinkage, and a sufficiently long firing range to permit their being fired to a ware that is vitrified or nearly so. Low-grade fire clays are sometimes employed.

Sewer Pipe

The kinds of clays and shales employed for this purpose are similar to those used for paving brick, but the clay is not always fired to a well-vitrified body, as the salt glaze which is applied during burning is relied on to close up the pores in the surface of the ware. All clays or shales will not salt glaze equally well, and even if the material does take the glaze, an excess of soluble salts may prevent it; consequently the clay should be free from these defects.

Fine grain, and thorough grinding are essential, as well as freedom from concretions of pyrite, siderite or lime carbonate.

The clay should show a moderate shrinkage, freedom from warping and cracking in drying and burning, and give a steel hard body.

At some works a mixture of low-grade fire clay and a red-burning shale are used.

Roofing Tile

These are commonly made from red-burning clays, of smooth texture, good plasticity, and capable of developing a steel-hard body at moderate temperature. On account of the flat shape of the tile and relative thinness of the body it is exceedingly important that the clay should show no tendency to warp or crack during the process of manufacture, and this calls for moderate shrinkage. The transverse strength should also be good, not less than 150 lbs. per sq. in. Unglazed tile should be steel hard and of low absorption, but not necessarily vitrified. Glazed tile while usually made of red-burning clays, are not always fired as dense as unglazed ones, but should be steel hard. The glaze whether dull or bright protects them from absorption of moisture.

In all cases the clay should be as free as possible from soluble salts. The clay which is used at Cloverport makes an excellent red tile at a comparatively low temperature.

Floor Tile

Two types of clay are used for this purpose, viz.: red-burning and white-burning clays. Red floor tile of different shapes and sizes, up to 6 inches square are made from a clay similar to that used for roofing tile. It is very essential that they fire to a dense hard body, not only for the purpose of resisting abrasion but also to prevent absorption of moisture. Porous tile should never be used in a floor.

White floor tile are never made from a natural mixture. They are manufactured from an artificial mixture of white-burning clays, ground flint, and ground feldspar, so compounded as to fire to a hard vitrified body. Artificial coloring agents may be added to give tile of blue, green and other colors. These too should be vitrified.

White Earthenware and Porcelain

These are made from artificial mixtures of kaolin, ball clay, ground flint and ground feldspar, so compounded that the body is steel hard but porous in the case of white earthenware, and vitrified in the case of porcelain. The body is fired first, glazed, and fired a second time.

The kaolin, of which none is found in Kentucky, is white burning, highly refractory, of fair to good plasticity, and usually low to moderate transverse strength. Its bonding power is not high.

The best ball clays burn to a white or faint creamy white body at cone 9, and have excellent plasticity. They usually have good transverse strength and bonding power, the former ranging from 187 to 387 lbs. per square inch, and the latter from 199 to 389 in a number of standard varieties tested.

The water of plasticity of a number ranges from 37.6% to 50.8%. The linear air shrinkage from 5.5% to 7.3%.

The following changes in porosity are also given by Parmelee*

	2010° F. 1099° C.	2100° F. 1115° C.	2190° F. 1199° C.	2300° F. 1260° C.
	%	%	%	%
English Ball Clay	1.99	.19	.68	.5
English Ball Clay	3.4	1.28	.90	.9
Tennessee Ball Clay	27.5	19.10	8.1	.7
Tennessee Bal Clay	22.3	16.40	8.4	2.4
Tennessee Ball Clay	20.7	13.90	3.7	2.3
Kentucky Ball Clay	19.0	12.70	1 3	1.3

The two following tests taken from Parmelee's report give the linear shrinkage of several Tennessee ball clays.

	I.	II.		III.	IV.
	%	%		%	%
1050° C.	.25	2.50	Cone 2	11.4	9.75
1125° C.	2.21	6.65	Cone 5	15.7	14.2
1200° C.	2.08	9.75	Cone 9	16.3	15.3
1320° C.	4.63	13.50	Cone 12	17.5	16.5

Sagger Clays

These are plastic, refractory clays of low shrinkage, and rather open-burning qualities, which are used for making saggers; receptacles in white ware and other high-grade wares are placed during burning, in order to protect them from the kiln gases and dirt. They do not have to be white burning. For making saggers a mixture of several clays and ground up old saggers may be used.

Wad Clays

These are non-refractory, siliceous clays, which are used for filling the joints between saggers when they are set one on top of the other in the kiln.

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*Resources of Tennessee, Vol. IX, No. 2, 1919.

*Total linear shrinkage. Linear air shrinkage III is 7.5 per cent, and of IV, 6.1 per cent.

Refractory Bond Clays

Refractory bond clay is a refractory clay which has even greater strength than a ball clay, and may burn dense at 1250°C. or even less. It is not necessary that the clay burn white. Such clays are used in glass refractories, graphite crucibles, abrasive wheels, etc.

Bleininger* suggests two classes, viz. A. Those showing a modulus of rupture of 325 lbs. per sq. in. or more, and B. Those whose modulus of rupture is between 225 and 325 pounds. The ratio of pore to shrinkage water should in no case exceed 1.00 for clays of the A type. For strong, heavy plastic clays, low in free silica, the ratio should not exceed .75, but some German siliceous bond clays, that have been much used, are not able to meet this requirement.

In burning, the overfiring temperature and the softening point are the principal criteria. For very severe service the clay should not develop a definite vesicular structure below 1425°C., nor a softening point below cone 31, but as Bleininger says, this specification may not be fair to some plastic clays, that are of use in the manufacture of graphite crucibles, especially for brass melting, although even for this purpose the temperature of overfiring should not be much below 1400° and the softening temperature not much below that of cone 30. Anything below these requirements should be ruled out as a bond clay. Bleininger suggests the following grouping of refractory bond clays according to their uses:

1. Clays specially suited for making graphite crucibles used for brass melting. They should burn dense at 1150°C. and show no evidence of overfiring at 1400°C. and have other required physical properties.

2. Clays for crucibles for melting steel. Should burn dense around 1275°C. and not overfire at 1400°C. or higher.

2a. Same as 2, but not overfire before 1425°C. These are valuable also for glass refractories.

*American Ceramic Society, Transactions, Vol. XIX, p. 601, 1917.

3. Clays especially suited for use in glass refractories. Those becoming dense only at 1425°C. or even higher, and not overfiring until 1450°C.

Of no value are those clays becoming dense anywhere between 1150°C. and 1300°, and showing either no range between these temperatures and overfiring, or only a short one.

The following figures give the properties of two Kentucky clays from the Purchase region as stated by Bleininger.

I. Described as very plastic, lacking in bonding power, as might be inferred also from the high ratio of pore to shrinkage water, viz. 1.05. The clay vitrifies to a dense structure at 1260°C., and remains quite constant to 1425°C., when it begins to overfire. Its refractoriness, cone 32, is satisfactory. It could be used in conjunction with a stronger clay as a bonding material for crucibles but would hardly be suitable for this purpose alone. It might be used in glass refractories with other clays of somewhat different properties. The high porosity of the clay at 1050°C., viz. 37 per cent, is indicative of its open structure in the dried state and explains the ready disintegration of the raw clay in water.

II. This clay has excellent working qualities and good strength. Its shrinkage water content is very high, being 77.4 per cent in terms of the true clay volume. Its pore-shrinkage water ratio is .71. It burns to complete vitrification at 1290°C. and begins to overfire at 1400°C. but this change is a gradual one. Its fusion point is cone 32. The clay is consequently an excellent bond clay especially suitable for steel melting crucibles and glass refractories.

		I.	II.
		%	%
Water in terms of dry weight		45.28	50.85
Water in terms of true clay volume		117.60	132.5
Shrinkage water in terms of true clay volume		57.20	77.4
Pore water in terms of true clay volume		60.40	55.1
Ratio pore water to shrinkage water		1.05	.71
Shrinkage by volume in terms of dry clay volume		34.53	46.80
Time of slaking, minutes		9.	36.5
Modulus of rupture, lbs. per sq. in.		239.	359.
Modulus of rupture, 1 clay; 1 sand, lbs. per sq. in.		234.	362.
1050° C.	Porosity	37.09	37.80
	Volume shrinkage	11.49	13.05
1075° C.	Porosity	33.90	30.90
	Volume shrinkage	16.83	22.70
1100° C.	Porosity	26.02	22.28
	Volume shrinkage	26.80	30.23
1125° C.	Porosity	21.25	18.25
	Volume shrinkage	30.90	33 30
1150° C.	Porosity	17.83	16.48
	Volume shrinkage	34.21	33.25
1175° C.	Porosity	17.05	13.90
	Volume shrinkage	35.40	34.70
1200° C.	Porosity	12.95	8.43
	Volume shrinkage	37.01	37.50
1230° C.	Porosity	6.13	3.46
	Volume shrinkage	39.00	39.02
1260° C.	Porosity	.19	2.45
	Volume shrinkage	41.20	40.55
1290° C.	Porosity	.81	.98
	Volume shrinkage	41.75	41.25
1320° C.	Porosity	.97	1.18
	Volume shrinkage	42.75	41.25
1350° C.	Porosity	.81	1.48
	Volume shrinkage	42.60	42.02
1400° C.	Porosity	.95	.84
	Volume shrinkage	42.80	40.80
1425° C.	Porosity	.33	2.76
	Volume shrinkage	42.10	39.75
1450° C.	Porosity	3.30	6.00
	Volume shrinkage	37.62	37.90
1475° C.	Porosity	4.88	.....
	Volume shrinkage	32.90	.....
1500° C.	Porosity	7.13	4.85
	Volume shrinkage	.....	35.60
Overfired at		1450°	1450°
Cone of fusion		32	32

CHAPTER III.

PURCHASE REGION

This portion of the state of Kentucky which lies west of the Tennessee River contains both high-grade clays used in the manufacture of whiteware, abrasives, crucibles, glasspots, stoneware, etc., and the lower grades of clay of value only for the manufacture of common brick and drain tile.

The Purchase region is underlain by a series of sand and clay formations of Tertiary age, which are known as Porters Creek and Lagrange and have a gentle dip to the westward, the clay being often in the form of lenses. Resting on top of this series of Tertiary beds is a deposit of ferruginous gravel known as the Lefayette formation which is also of Tertiary age and forms the overburden in most of the clay pits of Graves and Calloway counties.

On top of the Lafayette is a loamy and gravelly deposit of Quaternary age often referred to as the Columbian loam. It is usually iron stained and of no ceramic value except for the manufacture of common brick and tile.

Lastly there are flood-plain clays which are found underlying terraces bordering the rivers. The best deposits of these are those occuring along the Ohio River at Paducah.

The Porters Creek formation is 10-12 miles wide in Calloway County, but then as it extends northward towards Paducah the outcrop narrows, and the formation is concealed by alluvial deposits of the Ohio River before it reaches the northern boundary of the state.

In Kentucky the formation carries clay which has been opened up at several localities in Marshall County, and while the material is not of as high grade as the Lagrange clay obtained in Graves County, it can nevertheless be used in stoneware manufacture and for wad clay. The pits are located near Benton and Briensburg.

The Lagrange formation which overlies the Porters Creek stratigraphically, and hence outcrops to the westward of it, carries higher-grade clays, many of them being white or creamy

white after firing. Indeed the Lagrange is one of the most important clay-bearing formations of the Southern States, the product from the pits of Kentucky, Tennessee and Mississippi having an enviable reputation.

The deposits of the Lagrange include a series of clayey and sandy sediments which have been deposited in estuaries and in shallow water off shore during Tertiary times. They hence change from point to point. The sands are usually cross-bedded and sometimes ferruginous, while the lenses of clay, which are often large, are white, pink, brown, black or other colors, and range from materials which are so smooth and fine as to contain scarcely any grit to others which are rather sandy. A deposit of clay 25 feet thick may sometimes show beds of 4 or 5 different grades. Moreover the section seen in a given pit may vary from year to year as shown in the case of the pit at Pryorsburg. Beds of lignite may also be present but they are not as a rule more than a foot thick.*

The eastern border of the Lagrange formation in Kentucky passes through southwestern Calloway, northeastern Graves, middle McCracken and northern Ballard counties. It then swings westward into Pulaski County, Illinois.

At present the high-grade clay pits in the Lagrange have been developed only in the vicinity of Pryorsburg and Hickory. It seems not improbable however that there may be many others which cannot be profitably worked at present because they are too far away from the railroad and the roads are not good enough for long truck hauls.

There was not time to make a thorough investigation of all the unworked deposits in the Purchase region, and so examinations had to be confined to the active pits, and those deposits which were brought to our notice. In addition there have been included tests of other deposits that have been published.

Ballard County

The occurrence of high-grade clays in the vicinity of Wickliffe was mentioned by the Kentucky Geological Survey in 1888, and the deposits have been worked in a small way for some years.

*An exception to this rule is the deposit overlying the clay at Pryorsburg.

All of the openings are small and located close to the town of Wickliffe.

W. T. White has opened some pits about 2/5 of a mine south of Wickliffe.

The section measured in one showed:

	Ft.	In.
Sandy clay	4	
Black clay		8-10
Light gray sandy clay	10	

The other showed:

	Ft.	In.
Yellow-stained clay	2	
White sand		6
Sandy clay	5	
Black clay	3	

These two pits are controlled by the LaClede-Christy Clay Company of the St. Louis.

The American Clay Company of Muncie, Ind., has several openings about ½ mile northeast of Wickliffe.

The section in one of these measured in 1918, showed:

	Ft.
Gravelly overburden	3-7
Lignite	⅔-2
Clay	12½

The clays are sorted into several grades and used in glass-pot manufacture. Some of the clay obtained from here has a composition similar to the well-known Gross Almerode glasspot clay of Germany, but it is said to show a higher shrinkage and is softer when fired.

The pits were not very active during the season of 1921.

The following tests have been made by Easton, (Ref. 10, pp. 758-769), of some Ballard County clays.

1. Gray clay, southern part of Wickliffe, forming a bed 15 feet thick with a 2-foot layer of lignite. The amount of overburden is not stated. The properties given are: Plasticity, excellent; air shrinkage, 10%; fire shrinkage, 16%; cone of vitrification, 6; color fired, greenish yellow.

2. Harkless place, just north of Wickliffe. Clay dark gray; plasticity, high; air shrinkage, 7%; fire shrinkage, 7%; cone of vitrification, 8; color fired, pale yellow.

3. William Henderson place, 1 mile north of Wickliffe. Clay 7 feet thick, with 20 feet overburden. Color, light gray. Plasticity, high; air shrinkage, 5%; fire shrinkage, 5%; vitrification, above cone 11; color fired, white.

4. Property of C. Brown and Mrs. E. Linderman, 3 miles east of Blandville. Air shrinkage, 4%; fire shrinkage, 9%; vitrification, above cone 9; color fired, light buff.

5. One mile northeast of Blandville. A 10-foot bed of clay overlain by 42 feet of gravel and loam. Air shrinkage, 7%; fire shrinkage, 5%; vitrification, a little above cone 9; color fired, cream.

6. Samuels farm, 4 miles south of Blandville. Gray plastic clay, with 4 feet exposed, and 9 feet overburden. Air shrinkage, 5%; fire shrinkage, 2%; vitrification, about cone 9; color fired, gray white.

Calloway County

The high-grade clays of this county have been but little developed, some of those known being at present rather remotely located with respect to the railroad.

Ball and sagger clays are being dug just across the Kentucky-Tennessee line southwest of Crossland, Ky., but there are no active pits within the county itself, except those worked for stoneware.

The following localities were noted in the field:

Cherry. White and yellow clay occurs on the land of P. E. Stubblefield, 6 miles east of Murray and 1½ miles southeast of Cherry P. O. It shows up as pockets outcropping along the branch at the head of Panther Creek, the outcrops extending for over a hundred yards. The overburden is from 5 to 8 feet of loam and gravel, and it is claimed that the clay has been tested to a depth of 10 feet. The clay is thinly laminated and some of it is quite sandy. It also contains a thin bed of lignite. An apparent objection is the seeming irregularity of the clay. From the few tests that were made of it the material seems better

than a stoneware clay, but is probably not a high-grade ball clay. The material (Lab. No. 2436) has good plasticity and 6% linear air shrinkage. It fires to a cream white at the lower temperatures and becomes gray at 1430°C, with 6% fire shrinkage and 1.8% absorption.

Clay outcrops on the farm of B. D. Grogan, 3 miles southeast of Cherry, the gullies along the wagon road showing a light gray clay which appears to be fairly constant in character. Scattered through it are red specks, but these according to the potter at Pottertown do not affect its firing qualities for stoneware. The general section exposed is:

	Ft.
Loam	4
Gravel	2
Clay exposed	4-7

This is one of the most promising outcrops seen southeast of Murray, but at present haulage conditions are not good enough to permit its being worked. The following partial test of this clay (Lab. No. 2430) gives an indication of its character:

Air shrinkage (linear)	5%
Plasticity	Very good

Color after firing pinkish up to 1250° C. and gray at 1430° C.

	Fire shrinkage linear %	Absorption %
950° C.	0	
1070° C.	2	16.6
1250° C.	5	9.1
1430° C.	7.5	0.

It may be useful in stoneware, saggers, sanitary ware, or other purposes where a similar type of clay is required. It does not fire white enough for a ball clay.

Murray. Easton has described several other occurrences (Ref. 10, p. 771) near Murray as follows:

1. W. K. Russell place, 6 miles east of Murray. Thickness 4-10 feet; used for stoneware; plasticity good; color after firing, cream white; air shrinkage, 8%; fire shrinkage, 6%; vitrified at cone, 9; average tensile strength, 65 lbs. per. sq. inch.

2. A. B. Edwards place, 8 miles northwest of Murray on the road to Mayfield; clay exposed 5 feet thick, but amount of overburden not stated. Air shrinkage, 5%; fire shrinkage, 10%; color after firing, gray white; vitrifies at cone, 9. The test of this clay shows appreciably more shrinkage than the preceding.

3. On Nashville, Cincinnati and St. Louis Railroad property, one-half mile south of Murray, clay exposed, 10 feet; air shrinkage, 8%; fire shrinkage, 19%; average tensile strength, 69 lbs. per sq. in.; color after firing, dark red; vitrifies at cone, 11. The clay is of no value for high-grade wares, and its fire shrinkage at vitrification is too high.

The following additional occurrences were seen by Mr. Hodson, but they are at present too far from the railroad to warrant development.

On the Lynnhart farm, 12 miles southeast of Mayfield, numerous pockets of clay show along the creek bottoms. The clay in places is very light colored and sandy, but in others it is very smooth. There is 4 to 5 feet of gravelly overburden.

The best exposures of the clay are along the creek bottom about 1/4 mile southwest of E. C. Youngblood's house. Unfortunately the deposit is located too far from the railroad to be workable at present, if it should prove to be of workable quantity, and of satisfactory quality. The land in part surrounding the deposit is said to have been leased some years ago by a company in Ohio, but they have never worked the deposits. This property also adjoins the clay property controlled by the United States Clay Company, but this firm too has not done any development.

On the J. E. Chapman property which is located one mile northeast of Lynnhart's, and also 12 miles from Mayfield, a bank has been opened showing lenses of a grayish-black pottery clay. Other exposures are to be seen in the surrounding gullies. While Mayfield is the nearest railway station to this locality, Murray is the more accessible.

A sample (Lab. No. 2479) from the Flower property, near Murray, Calloway County, was given a partial test. It shows good plasticity with a linear air shrinkage of 5%. At 1330°C. it fired to a steel hard, cream-colored body, with 3.5% fire

shrinkage and 6.3% absorption. It does not burn white enough for a good ball clay but might be used in saggers.

A partial test of the Lynnhart Clay (Lab. No. 2435) indicates that it is a white clay of good plasticity, but not white burning. It fires to a cream color, and at 1430°C is gray and vitrified with 10% fire shrinkage. The material is too far from the railroad to be utilized at present.

Pottertown. There is one pottery in operation in Calloway County. This is run by Falwell and Son at Pottertown, with Almo as the postoffice address. The product consists of common stoneware.

The clay is hauled by trucks from pits located to the south of Pottertown, but it is not considered to be as satisfactory as that in the old Russell pits which are near the pottery and which have recently been purchased from W. D. Russell who used to operate the plant.

The Russell pits which will be drawn upon in the future contain two grades of clay. One is very smooth and resembles a ball clay while the other one is more sandy and has a lower shrinkage as well as being easier to work. The two grades are mixed in about equal proportions.

The ware which includes crocks, jugs, urns, and other stoneware articles is thrown on a wheel, and fired in a small circular down-draft kiln. The body of the ware which is dense, steel hard and of light-buff color, is covered with a glaze of Albany slip.

The product finds a ready market in the surrounding country, being distributed by auto truck.

Carlisle County

No clays have been developed in Carlisle County.

The following partial tests are given by Easton (Ref. 10, p. 773) but nothing is known regarding the extent of the deposits.

1. One mile northeast of Laketon, on Marion Hogencamp place. Clay 6 feet thick. Air shrinkage, 7%; fire shrinkage, 9%; tensile strength, lbs. per. sq. in., 134; vitrified, cone 11; color when fired, pink.

2. Four miles northeast of Milburn, Mrs. E. J. Carrico property. Clay, sandy; air shrinkage, 8.3%; fire shrinkage, 4.6%; tensile strength, lbs. per sq. in., 164.5; vitrifies at cone 5; color when fired, buff.

3. Two and one-half miles north of Laketon on Dr. T. S. Terrell's place. Clay, plastic; air shrinkage, 9%; fire shrinkage, 5%; tensile strength, lbs. per sq. in, 197.5; cone of vitrification, 9; color when fired, buff at lower cones, gray at higher ones.

4. Three miles north of Buckley on William Reynolds place, clay 8 feet thick and very plastic. Air shrinkage, 9%; fire shrinkage, 5%; tensile strength, lbs. per sq. in., 112.6; cone 6, color pink, turned yellow at cone 9.

Fulton County

There is no clay industry developed in this county.

Easton (Ref. 10. p. 793) notes a clay occurring in the Mississippi bluffs on the north side of town along the Nashville, Chattanooga and St. Louis Railroad, which has a maximum overburden of 45 feet. The clay is very plastic, with 9% air shrinkage and a tensile strength of 206 lbs. per sq. in. It has no grit. In firing the clay becomes yellow at cone 1, but turns red at a higher cone. If it is so free from grit it might be worth looking into as a pencil clay.

Graves County

This county contains most of the ball and sagger-clay pits that have been opened up in the Purchase region.

Pryorsburg. Two companies have opened up pits at this locality, but only one was in operation in the summer of 1921.

Kentucky Construction and Improvement Company. This company whose main office is at Mayfield, has pits located on the east side of the Illinois Central Railroad, and has been in operation since 1891. The deposits are said to underlie about 50 acres.

The following notes are taken chiefly from a forthcoming bulletin of the United States Geological Survey, prepared by the writer*:

*Published by permission of Director, U. S. Geological Survey.

The clay lens which is evidently a large one appears to trend in a direction 20° east of south, and its upper surface within the limits of the excavation is fairly level, while the overburden because of surface irregularities varies from 36 to 60 feet.

The first column below is a section of the deposit, measured in 1918, while in the second column is shown the same section as measured in November, 1921. The comparison is of interest as showing how the individual beds may change in thickness within a comparatively short distance:

	Ft.	In.	Ft.
Sandy clay	6		
Gravel	3½		
Orange colored sand	4½		
Gravel	2		
Orange colored sand	1½		
Interbedded sand and clay lenses	1		
Variegated sand	5½		
Hard pan ironstone	.....	6	
Tough brown clay	.....	6	
Lignite and lignitic clay, of local occurrence	0-12		
Sagger clay No. 1	3½		3½
Ball clay No. 2	5½	Dark band No. 2 ball	1½ 3
Dark clay (black ball)	1		1½
Ball clay No. 3	4½		⅓
Clay, colored some by lignite	1½		2
Highly lignitic clay	6½		
Ball clay No. 4, chocolate colored with light motlings	5		3½
Ball clay No. 5	4½-5		3½
No. 6 fire clay	10		12
No. 7 sand	4		4

This section is quite varied, and probably shows a greater number of beds than any other section measured in western Kentucky or Tennessee.

Immediately under the overburden of gravel and sand, at the north end of the pit is a lens of lignite which is 12½ feet

thick in the center, but tapers out to nothing in both directions. It is mostly fine grained and contains few woody fragments.

In addition to the data given in the section the following facts may be added:

The sagger clay, which is light gray, with a dark seam in the center seems to be missing in the old pit nearby, that the company formerly worked.

The No. 3 ball clay, corresponds to No. 4 of the old mine, where it lies directly below the lignite. This is used in the manufacture of crucibles, tiles and whiteware. It is also said to have been employed as an ingredient of steel enamels. The highly lignitic clay between this and the next lower ball clay is thrown out. In 1921 there was being shipped a black ball clay designated No. 4.

Fig. 4. General view of portion of pit of Kentucky Construction and Improvement Company, Pryorsburg.

The clay No. 7 is chocolate above, lighter below, the whole showing somewhat bright colorings. It is of value in glass-pot work.

Underlying the ball clays are several beds usually referred to as fire clays, and which have been opened up at a lower level.

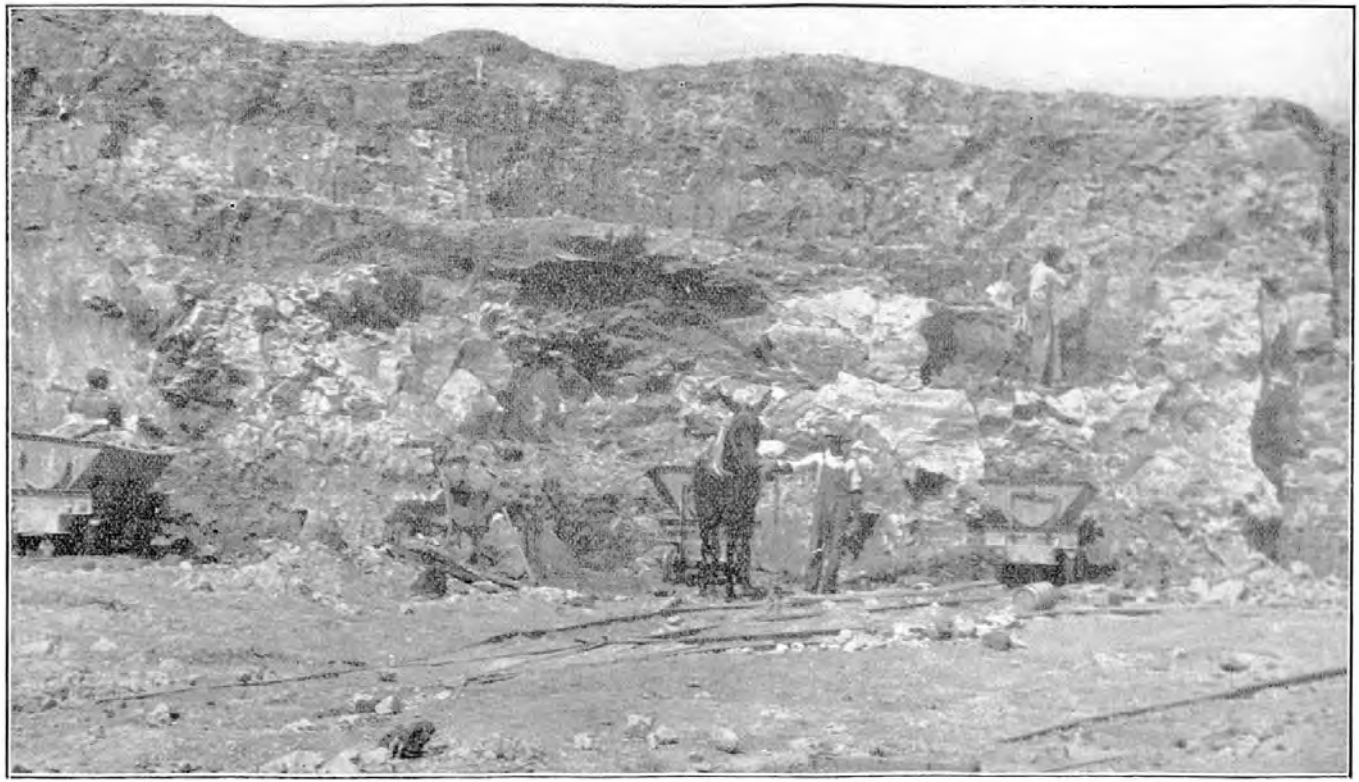


Fig. 5. Digging ball clay, Kentucky Construction and Improvement Company, Pryorsburg.

They appear somewhat similar but are separated into several grades. The upper one known as No. 5 ball is mixed with the lower fire clay and is of use in the clay bond of abrasive wheels.

No. 6 next underlying is used to some extent in glass-pot mixtures and also for bats in abrasive-wheel work.

No. 7 lies next below and is not as short as No. 6.

The pit is a large opening, but the working is being done chiefly at the south end.

After removing the overburden with steam shovel, and a large amount of this was being done in 1921, the clay is dug with mattock and shovel. It is then loaded on to small cars of 1-ton capacity which are hauled to the foot of an incline and drawn up to the storage bins.

A miscroscopic examination and also a few fire tests were made of several of the clays from this pit with the following results:

No. 3 ball clay of non-lignitic character is very plastic, smooth and fine grained. It contains a very little quartz, but a great abundance of hydromica. Kaolinite is common, but rutile is scarce. It burns to a light cream color at 1330°C. with 11.4 per cent porosity. A thin section of the fired clay examined under the miscroscope shows an exceedingly fine-grained, felt-like appearing mass with low interference colors.

Old No. 4 ball clay is also a very smooth plastic clay with very little quartz. At 1330°C. it fires to a cream-white color with 11.5 per cent porosity.

The No. 5 fire clay is medium to fine grained, but is very plastic and smooth. Under the microscope it shows little quartz, with hydromica common, and kaolinite much more abundant. Rutile occurs sparingly. At 1330°C. the clay showed 28.7% porosity. Its color was creamy-white.

The following two tests were made by the Bureau of Mines, and are noted, herewith, by permission of the Director of the United States Geological Survey:

Ball Clay Old No. 4

AVERAGE DATA ON CLAY ALONE

Moulded into bars—

Workability. Very plastic, sticky. Pulls up under spatula.

Per cent tempering water in terms of dry clay 41.72

Per cent drying vol. shrinkage in terms of dry clay 31.92

Burned Data.

Temp. of Firing.	1190° C.	1250° C.	1310° C.	1370°C.	1410° C.
Per cent Porosity— terms of burn. vol.....	16.7	16.79	1.59	0.9	0.3
No. bars	3	3	2	3	3
Per cent vol. skg.— terms of dry clay	32.0	29.89	37.52	40.0	38.0
No. bars	3	3	3	3	3

Modulus of rupture ..... 25.55 lbs. per sq. in.

Modulus of rupture, 50% sand .....196.3 lbs. per sq. in.

Deformation temperature is Cone 32 Final.

Ball Clay No. 5

AVERAGE DATA ON CLAY ALONE

Moulded into bars—

Workability. Plastic, tough. Moulds well. Warped in drying.

Per cent tempering in terms of dry clay 34.47

Per cent drying vol. shrinkage in terms of dry clay 26.34

Burned Data.

Temp. of Firing.	1190° C.	1250° C.	1310° C.	1370°C.	1410° C.
Per cent porosity— terms of burn. vol...	18.3	18.33	10.84	0.6	0.4
No. bars	3	3	3	3	3
Per cent vol. skg.— terms of dry clay	28.3	29.64	33.41	38.2	37.5
No. bars	3	3	3	3	3

Modulus of rupture .....189.1 lbs. per sq. in.

Modulus of rupture, 50% sand .....167.5 lbs. per sq. in.

Deformation temperature is Cone 31 Final.

Screen test. 1.27% remains on 150 mesh.

The following analyses and tests of clays from this company's pits have appeared in an earlier report of the Kentucky Geological Survey. (Ref. 10, p. 797):

	I.	II.	III.	IV.
Silica	51.92	57.72	53.76	49.32
Alumina	30.36	24.84	29.04	32.64
Ferric oxide	1.60	1.44	1.12	1.44
Ferrous oxide	tr.	tr.	tr.	tr.
Lime	.32	.38	1.32	.34
Magnesia	tr.	tr.	tr.	tr.
Potash	1.28	.92	.99	1.03
Soda	.45	.28	.31	.29
Titanic oxide	1.00	2.20	1.80	1.00
Water	11.66	10.74	9.89	12.40
Moisture	2.13	1.45	1.32	1.91
	99.72	99.97	99.55	100.37
Air shrinkage, per cent	7.0	5.0	3.0	5.0
Fire shrinkage, per cent	10.0	8.0	7.0	10.0
Tensile strength per lb. per sq. in.	60	54	40	51
Cone of vitrification	7	9	6	6
Color	Gray White	Gray White	Gray White	Gray White
Plasticity	Excellent	Excellent	Good	Excellent

I. Oliver No. 2 ball clay.
II. Oliver No. 4 ball clay.
III. Oliver No. 5 ball clay.
IV. Old mine No. 4 ball clay.

Mayfield Clay Company. The Mayfield Clay Company has a pit located on the west side of the Illinois Central Railroad near Pryorsburg station. It was opened up in 1917 but has been idle for about two years, I am informed. The pit lies at a slightly lower level than the one just described, and the clay is of a totally different color, being all grayish-black. Part of it shows sandy laminae which give it a stratified structure.

A section as measured in 1918, showed:

	Ft.
Sandy loamy clay	6
Sand	4
Gravel	3-5
Sagger clay	4
Ball clay	9
Wad clay	3½
Sand, thickness unknown	.....

The company was said to have tested out about 7 acres showing 18 to 23 feet of clay.

The clay is separable into several grades. A sample of the No. 3 ball clay is fired to 1330°C. showed 7.6% porosity, and was of a light buff color.

Fig. 6. Clay pit, Old Hickory Clay and Talc Company, Hickory.

A sample of the sagger clay fired to a cream-white color with 11.9% absorption at 1330°C.

Hickory. Lying to the west and southwest of Hickory are a number of clay pits operated by different individuals or com-

panies, which in the aggregate are capable of supplying considerable clay of ball and sagger grade. In the summer of 1921 they were not all in active operation on account of the depressed condition of business.

Old Hickory Clay and Talc Company. The Old Hickory Clay and Talc Company has a pit located on the D. M. Chapman farm, 2 miles southwest of Hickory station, the clay being hauled by auto truck to storage sheds along the Illinois Central Railroad, south of Hickory.

This pit, (Fig. 6), was first opened up in 1918, and has been considerably developed since that time. The section at present exposed shows:

	Ft.
Gravel and sand overburden	8-23
Sagger clay A	8-10
Ball clay B, slightly mottled	6-8
Dark brown lignitic clay, with grains of resin	½
Ball clay C, lower part bluish gray in places	3-10
White sand.	

The deposit is worked as an open pit, the clay being loaded into a large iron box which is hoisted to the top of the pit.

The beds A and B are mixed for saggers. Clay B is used in electric porcelain, sanitary ware, etc.

The following tests were supplied by the Old Hickory Clay and Talc Company.

GRADE A SAGGER CLAY

Plasticity	Very good
Water of plasticity	26%
Linear air shrinkage	7%
Volume air shrinkage, in terms of dry volume	25%
Modulus of rupture, pounds per square inch	280
Bonding strength, 1:1 clay sand mixture, lbs. per sq. in.	137
Slaking time in minutes, clay alone	23
Slaking time in minutes, 1:1, clay-ground flint mixture	9
Residue on 200 mesh	.3%
Steel hard	1150° C.

Firing tests.

Temp.	Linear Fire Shrink.	Vol. Fire Shrink.	Absorption	Porosity	Color
1150° C.	.....	.....	13.08	27.30	Cream white
1230° C.	7.25	20.00	11.00	23.75	Light cream
1270° C.	10.00	22.00	9.80	21.70	Cream white
1310° C.	9.00	22.50	7.50	17.80	Light cream buff
1370° C.	10.50	30.00	3.90	9.00	Pale buff
1450° C.	11.50	35.00	3.50	9.40	Gray

This clay works up well and has good strength in the unburned condition. The color after firing is good, but it is a little too open burning to be classed as a typical ball clay. The shrinkage is not excessive. It should be of use in the manufacture of saggers, chemical stoneware, abrasives, and other uses to which this type of clay is put.

GRADE B BALL CLAY

Plasticity	Very good
Water of plasticity	37.7
Linear air shrinkage	6.7
Volume air shrinkage, in terms of dry volume	25%
Modulus of ruputre, pounds per square inch	249
Bonding strength, 1:1, clay sand mixture, lbs. per sq. in.	137
Slaking time in minutes, clay along	20
Slaking time in minutes, 1:1, clay-ground flint mixture	8
Residue on 200 mesh	.1%
Steel hard	1150° C.

Firing tests.

Temp.	Linear Fire Shrink.	Vol. Fire Shrink.	Absorption	Porosity	Color
1150° C.			14.2	27.90	
1230° C.	11.75	27.5	9.5	20.10	Cream white
1270° C.	12.50	32.80	7.8	19.00	Cream white
1310° C.	13.00	35.00	3.8	9.60	Cream white
1370° C.	14.00	38.00	.7	3.00	Gray
1450° C.	13.50	42.5	.9	3.30	Gray

This clay shows a good transverse strength in its unburned condition, and a fair degree of vitrification at 1310° C. The color of the fired clay is good. It is a good ball clay though not quite as dense burning as some. It should be of service for the various uses to which ball clays are put.

BALL CLAY C.

Plasticity	Very good
Water of plasticity	40%
Linear air shrinkage	6.5%
Volume air shrinkage, in terms of dry volume	30%
Modulus of rupture, lbs. per sq.. in.	401
Bonding strength, 1:1, clay sand mixture, lbs. per sq. in.	143
Slaking time, in minutes, clay alone	15
Slaking time, in minutes, 1:1, clay-ground flint mixture	7
Residue on 200 mesh	.2%
Steel hard	1150° C.

Firing tests.

Temp.	Linear Fire Shrink.	Vol. Fire Shrink.	Absorption	Porosity	Color
1150° C.			12.9	30.1	
1230° C.	11.0	25.6	9.1	19.4	Faint cream white
1270° C.	12.5	35.9	7.7	17.9	Light cream
1310° C.	12.5	35.9	6.2	16.0	Cream white
1370° C.	15.0	36.8	.8	3.8	Gray buff
1450° C.	16.0	40.0	.4	2.5	Gray

This clay has excellent plasticity and strength in the unburned condition. It fires to a good color up to 1310° C., but above that darkens a little. It is a little more open burning than the typical ball clay, but mixing it with the D grade would improve it. It should be of value for those uses to which ball clays are put.

BALL CLAY D.

Plasticity	Very good
Water of plasticity	31.5%
Linear air shrinkage	5.25%
Volume air shrinkage	26.8%
Modulus of rupture, lbs. per sq. in.	263
Bonding strength, 1:1, clay sand mixture	102
Slaking time, in minutes, clay alone	15
Slaking time, in minutes, 1:1, clay-ground flint mixture	5
Residue on 200 mesh	Trace
Steel hard	1150° C.

Firing tests.

Temp.	Linear Fire Shrink.	Vol. Fire Shrink.	Absorption	Porosity	Color
1150° C.....			11.6	24.4	
1230° C.....	8.7	21.9	7.5	16.9	Light cream
1270° C.....	11.	34.00	6.0	14.0	Light cream buff
1310° C.....	11.	34.00	1.4	5.1	Cream white
1370° C.....	11.	34.1	.2	1.1	Gray
1450° C.....	10.5	48.8	.2	.4	Gray

This clay has good plasticity and good strength in the unburned condition. It fires to a good color. At 1310° C. the porosity is low, as might be expected in a typical ball clay. This is the densest burning of the four samples. It should serve well for those purposes requiring a typical ball clay.

Fig. 7. Pit of Colonial Clay Company, Hickory.

Colonial Clay Company. The Colonial Clay Company has opened a small pit on the A. Wyatt farm, 2½ miles southwest of Hickory and a short distance west of the pit of the Old Hickory Clay and Talc Company.

The opening, (Fig. 7), which was idle at the time of our visit was about 30 feet diameter, and the exposed section showed:

Gravel	12 ft.
White clay	6 ft.

The material is said to be a sagger clay.

M. B. Cooley Clay Company. This company has an opening about one mile west of Hickory and just north of Mr. Cooley's house. A deep excavation of relatively small diameter

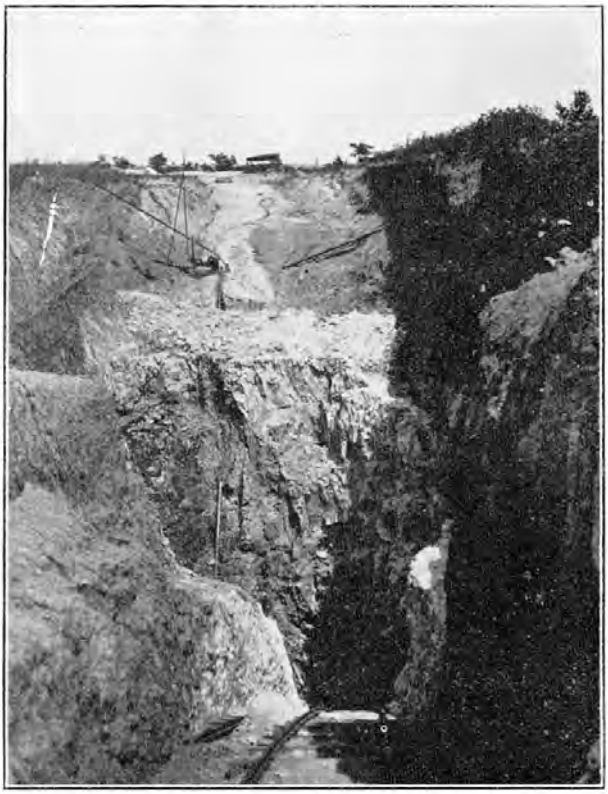


Fig. 8. Pit of M. B. Cooley Clay Company, Hickory.

has been made showing 8-15 feet of gravelly overburden, and about 50 feet of clay. It was not being operated at the time of our visit. A storage and drying bin has been erected near the pit and from this a sample of the smoothest material was taken for a partial test. The results are given below.

The material (Lab No. 2466) is a smooth whitish clay, probably from bottom of deposit:

Plasticity	Good
Slaking time	13 minutes
Air shrinkage (linear)	4%
Fired at 1250° C.	
Fire shrinkage	12%
Absorption	20.9%
Color	Faint creamy white
Steel hard.	
Fired at 1430° C.	
Fire shrinkage	16%
Absorption	0%
Color	Gray

It is of the ball-clay type but rather open-burning at 1250°C.

Excelsior Clay Company. The Excelsior Clay Company with head office at 31 W. 13th St., Cincinnati, has a pit 2 miles west of Hickory station, and hauls its clay by wagon to the railroad.

In 1918 the section on the west side of the pit showed:

Gravel	9-12 ft.
Sagger clay	15-16 ft.

On the east side of the pit about 50 feet distant the section was:

Overburden	10 ft.
Light bluish-white ball clay	6 ft.
Sagger clay, gray, with red mottlings	2 ft.

In the summer of 1921 the pit had been developed about 300′ farther west, showing:

Loam	3-8 ft.
Gravel	8-10 ft.
White sand	0-15 ft.
Sagger clay (not all exposed)	15 ft.
White sand.	

These several sections are interesting as showing how the Lagrange clay deposits may vary from point to point.

A partial test of a sample (Lab. No. 2465) taken from the stock pile showed:

Plasticity ..... Good
Slaking time ..... 19 minutes
Air shrinkage (linear) 5.5%
Fire tests.

Temp.	Fire Shrink. %	Absorption %	Color
1250° C.	11	8.5	Creamy white
1310° C.	17	.3	Cream
1430° C.	14	.....	Gray

The clay does not burn white enough for a ball clay, but can be used for saggers.

Fig. 9. Pit of West Kentucky Clay Company, Hickory.

West Kentucky Clay Company. The West Kentucky Clay Company has opened up a pit about 2 miles south of west from Hickory. It is said to have 60 acres leased and to have tested

out the clay to a depth of 30 feet by boring. The pit (No. 9) was not in operation when visited and showed:

Gravelly overburden	10-20 ft.
Clay, exposed	4.10 ft.

The upper limit of the clay is rather uneven, but the deposit is opened up on a hillside so as to make it self-draining. It is said that only sagger clay has thus far been shipped, but under this it is claimed that there is a bed of pink ball clay and one of chocolate ball clay the two being separated by a layer of lignite. These ball clays were not exposed.

Kentucky Clay Mining Company. The Kentucky Clay Mining Company has a pit (Fig. 10) located two miles west of Viola, the clay being hauled to the railroad by teams and auto truck. The pit is a comparatively recent development. At the time it was visited the section showed:

Gravel	6-10 ft.
Reddish clay, sagger	4-5 ft.
Dark gray clay, in places with sandy laminae, and also leaf impressions	15 ft.
Sand	.....

The grayish-black clay closely resembles that found in the pit of the Mayfield Clay Company at Pryorsburg. It is separated into several grades as sagger, ball and wad clay.

Some partial tests were made on samples from this pit as follows:

Grayish-black clay from 2d stratum
(Lab. No. 2469)

Plasticity	Good
Slaking time	35 minutes
Air shrinkage	6%

Temp.	Fire Shrink. %	Absorption %	Color
950° C.	2.5	20.0	White
1250° C.	9.0	9.6	Light creamy white
1310° C.	10.5	6.0	Light cream

Steelhard 1250° C.
Porosity at 1310° C. 15.2%.

Fig. 10. Pit of Kentucky Clay Mining Company, 2 miles west of Viola.

So far as its burning qualities are concerned the material fires to a color that would make it of use in whiteware, although its density at 1310°C. is not very low.

Grayish-black Clay, 3d stratum (Lab. No. 2467)

Plasticity	Good
Slaking time	11 minutes
Air shrinkage	7%

Fire tests.

Temp.	Fire Shrink.	Absorption	Color
	%	%	
950° C.	3.	22.0	White
1250° C.	8.5	12.1	Faint creamy white
1430° C.	11.5	0.	Gray

The color of this clay after firing is good, but it does not burn as dense as some of the other beds in the pit. It should be of use in whiteware, saggers, and other purposes for which a clay of this type is demanded. It has also been used for modeling.

No. 4 Ball clay (Lab. No. 2468)

Plasticity	Good
Slaking time	8 minutes
Air shrinkage	7%

Fire tests.

Temp.	Fire Shrink.	Absorption	Color
	%	%	
950° C.	2.	.....	White
1250° C.	7.5	10.0	Faint creamy white
1430° C.	10.5	0	Gray

Porosity at 1310° C. .5%.

The color after firing is good, and it could probably be used in sanitary ware, chemical stoneware, saggers, etc.

Brick and Pottery Plants. The only plants in operation in the county are a pottery at Bell City and a brick plant at Mayfield.

Bell City Pottery. The Bell City Pottery operated by W. D. Russell is located at Bell City on the Mayfield-Paris road. The product is common stoneware.

The clay deposit is situated just east of the Pottery and underlies 3 to 4 acres, and the section exposed shows:

Surface clay loam	2-3 ft.
Dark fat clay	3-4 ft.
Light gray sandy clay	4 ft.

The two lower beds, which contain abundant leaf impressions, are mixed for use.

The clay is tempered in a ring pit, and molded on a potter's wheel which is operated by a gasoline engine. Firing is done in a circular down-draft kiln with wood fuel. It requires 60 hours, and the completion of the process is judged by trial pieces. Albany slip clay is employed for glazing. The ware is disposed of in the surrounding country.

Mr. Russell formerly operated the stoneware plant at Pottertown, and his present one is evidently the same as that referred to by Easton (Ref. 10, p. 795) under the name of W. B. Howard and Son. In that report Easton speaks of the plant having used a 10-foot bed of very plastic white clay.

For this clay he gave: air shrinkage, 5%; fire shrinkage, 9%; tensile strength, 25 lbs. per sq. in.; vitrification, cone 11; color, white at cone 1 and dove gray at vitrification.

The analysis given by Easton is:

Silica	68.54
Alumina	19.92
Ferric oxide	.80
Ferrous oxide	tr.
Lime	tr.
Magnesia	.70
Titanic oxide	1.20
Potash	1.66
Soda	.24
Water	6.25
Moisture	1.10
	100.41

Standard Brick Works. The Standard Brick Works of Mayfield is located just beyond town along the Pryorsburg road, and on the western side of the Illinois Central Railroad.

The clay used is a surface loam of Columbian age and is dug just west of the works. The bricks are molded in a dry-press machine, and the plant is equipped with 5 circular and 1 rectangular down-draft kilns. The product is a good red color and has a good ring.

Hickman County

No high-grade clay is mined in this county, and none appears to have been in the past.

Easton (Ref. 10, p. 847) describes a clay occurring in the so-called "chalk banks" below Columbus. It is said to lie in the Lagrange formation, is 35 feet thick, and of a dark gray color. It has the following properties:

Plasticity	Moderate
Air shrinkage	0%
Tensile strength, lbs. per sq. in.	48
Fire shrinkage	2.5%
Vitrification cone	+11
Color when fired	Cream

A second sample, from a 10-foot bed lying below the preceding, has 10% air shrinkage, 0% fire shrinkage and is vitrified at cone 11.

The only clay-product plants in this county are two brick yards, neither of which have been in operation for several years.

One of these is that of J. A. Harpole at Columbus, who used to make common brick from a yellow surface clay. The other is that of Thomas Boodman at Clinton.

Marshall County

Several clay pits have been opened in this county, but only one of them appears to be a steady producer. They all lie in the Porter's Creek formation, which stratigraphically is next below the Lagrange and do not yield as high-grade clays as the latter.

As there have been few changes in the industry in this county in the last few years we may quote from a forthcoming report of the United States Geological Survey, prepared by the writer.*

Benton. Several pits have been opened up in the vicinity of Benton, but they have been worked sporadically to supply a local demand.

One of these openings known as the Howard pit, is located 1 mile northwest of Benton, and is a shallow excavation covering about half an acre. The total thickness of the clay is 12 feet, of which 5 to 7 feet is a black laminated clay and the rest a sagger clay. The clay appears to thin out to the southward. The wad clay from the Howard pit is of fair plasticity, but rough textured and to the eye shows a few mica scales and finely-divided organic matter.

A sample fired to 1330°C. showed 12% absorption, 24.5% porosity and was buff colored.

About ½ mile west of the Howard pit, and along the highway leading north from Benton, clay again outcrops in a high bank. It lies at a higher level than the Howard pit and may be a different deposit. The overburden is 8 feet but increased rapidly to the east due to the rise of the surface.

About 3½ miles north of Benton, there are two other pits on the Lofton property, which have been worked some in the past to supply the Paducah Pottery Company. The clay is said

*By permission of the Director, U. S. Geological Survey.

to underlie 40 acres. It is sandy, about 15 feet thick, and underlain by sand, while above it is a gravelly conglomerate and hardpan, whose thickness is not less than 8 or 10 feet.

Briensburg. The Paducah Clay Company has opened up a deposit for pottery use 2 miles east of Briensburg. (Fig. 11.)

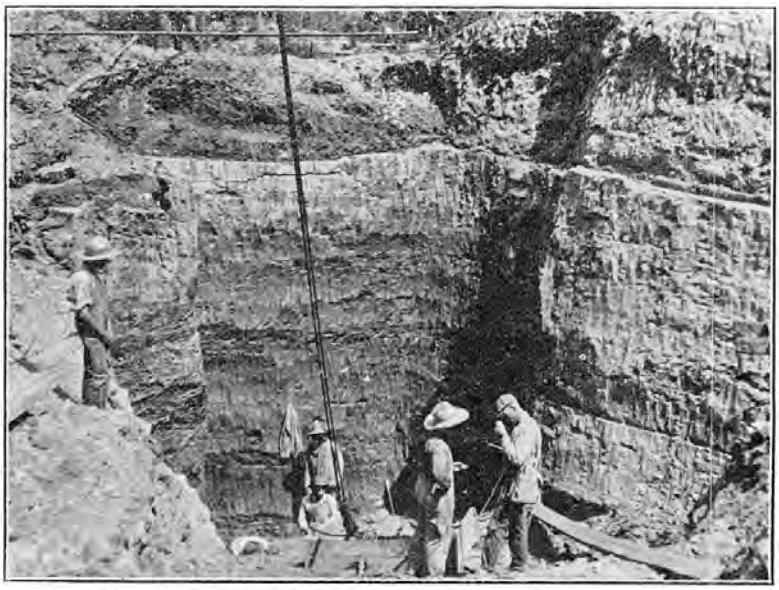


Fig. 11. View in pit of Paducah Clay Company, showing black clay.

In 1918 there was on one side of the excavation a square pit showing 30 feet of clay. This material is black, dense, and plastic, but contains sandy laminae from 2-6 inches apart. Flat pyrite concretions lying along the bedding planes are scattered through the deposit, but these are thrown out in mining. Near the bottom of the clay there are thin layers of glauconitic sand.

The amount of overburden is variable. It was 4 feet where the clay was being dug in 1918, but in 1921 the pit showed 8 feet of gravel and 14 feet of orange sand on top of the clay.

The clay is used in stoneware and saggers.

A sample of the clay fired at 1330°C. was grayish brown with 5.6 per cent absorption and 12.9 per cent porosity. It is steel hard.

The clay is hauled by truck to Paducah where it is used in the manufacture of stoneware.

Miscellaneous Tests. The following tests of clays from different localities in Marshall County are given by Easton. (Ref. 10, p. 865):

	I.	II.	III.	IV.
Silica	55.90	65.10	63.20	60.60
Alumina	26.34	22.18	23.32	25.06
Ferric oxide	2.24	1.28	1.22	1.36
Ferrous oxide	.28	.28	.22	.43
Lime	tr.	tr.	.....	.....
Magnesia	1.01	.80	tr.	tr.
Sulphur trioxide	tr.	.....	.....	.....
Potash	1 89	1.38	1.41	1.40
Soda	.33	.37	.32	.24
Titanic oxide	1.00	1.12	1.10	1.00
Water	8 86	6.89	7.57	8.45
Moisture	1.93	1.10	1.10	1.25
	99.78	100.50	99.46	99.79
Plasticity	Fair	Excellent	Fair	Excellent
Air shrinkage	5.0%	5.0%	7.5%	5.0%
Fire shrinkage	9.0%	5.0%	7.5%	6.0%
Tensile strength, lbs. per sq. in.	63	55	65	42
Cone of vitrification	9	11+	6	10
Color when fired	Drab	White	Buff	Cream

I. L. Faust, 2 miles east of Palma.

II. Wm. Bunadell place, near Bryantsburg and Gilbertsville road, 2½ miles north of Bryantsburg. A micaceous, rather sandy, whitish clay.

III. Same locality as II.

IV. Lon Lofton clay, on Paducah and Benton road at Scale. White clay with iron mottlings.

McCracken County

This county is important for the location of clay products factories, rather than as a producer of raw clays. All the works, two brick plants and one pottery, are located in the city of Paducah.

Paducah Pottery Company. This company has a plant, which produces stoneware, the clays being obtained in part from Kentucky and in part from Indiana.

Paducah Brick and Tile Company. The Paducah Brick and Tile Company, located on south 10th St., produces common building brick only.

The clay used is a flood plain clay of the Ohio River, the pit being situated about 400 feet south of the works. The material is a tough red clay, and the bottom of the bank, whose face is about 25 feet high, is 30 feet above river level. Below the red clay is a tough blue clay that was formerly mixed with the upper clay and used in the manufacture of hollow block and tile. It is not used now.

Fig. 12. Clay pit, Paducah Brick and Tile Company, Paducah.

The bricks are molded in a soft-mud machine, and dried on pallet racks. Firing, which takes 12 days, is done in Dutch kilns. The clay shows 12 inches settle in 41 courses.

The market is chiefly western Kentucky and Tennessee.

Hill and Karnes. This firm operates a common brick plant at 900 North Sixth Street. The material used is a flood-plain clay, dug about 25 feet above river level.

The bricks are molded in a soft-mud machine, dried on pallet racks, and fired in Dutch kilns. During burning there is 12-14 inches settle in 42 courses. The product is a good common brick, but selected brick are sold for fronts. The market is the same as the preceding.

Miscellaneous Operations. Some clay development is said to have been attempted by the Paducah Clay Products Company on the Contest road, 5 miles southwest of Paducah, but no definite information is obtainable regarding the operation.

Easton (Ref. 10, p. 869) gives the following physical tests of some clays in McCracken County:

Color fired	Gray white	Gray white	Gray white	Light gray	Yellow	Red	Yellow Brown
Plasticity	Good	Good	Excel.	Good	Fair	Good	Good
Air shrinkage	5%	5%	5%	9%	2%	8%	7%
Fire shrinkage	9%	12%	13%	9%	3%	12%	8%
Tensile strength, lbs. per sq. in.	.....	.....	50	.....	70	82	61
Cone of incipient fusion	9	9	9	.....	.....	1	4
Cone of vitrification	11	11	11	11	11+	6	9

I. 8 miles south of Paducah. Six feet of clay. Sample tested represents upper 2 feet.

II. Lower 4 feet of I.

III. Upper 4 feet of a 6-foot bed, 7½ miles south of Paducah on Contest road.

IV. Lower 3 feet of III.

V. V. Welch property on Lone Oak-Mayfield road, 3 miles from Lone Oak.

VI. R. Bell property on Paducah-Mayfield road, 4 miles south of Paducah. Clay 6-12 feet thick in Lafayette formation.

VII. G. Munier property, 5½ miles south of Paducah on same road as VI.

Paducah. The following tests were supplied by Dr. R. R. Winston, of Paducah. They were made on samples taken from a clay deposit located 4 miles south of Paducah. The chemical analysis was made on material taken from eight feet below the surface, while the physical tests were made at the Bureau of

Standards on samples taken from 15 and 26 feet below the surface. The chemical analysis gave:

Silica	52.90
Alumina	33.30
Ferric oxide	2.01
Lime	.48
Magnesia	.75
Alkalies	1.35
Water	9.21
	100.00

A physical test made by the Bureau of Standards is reported as follows: "The clay was of a black color and possessed good plasticity and working qualities. The water required for the plastic state was 55.5% in terms of the dry weight, and the volume shrinkage was also very high being 66.1% in terms of the dry volume. In firing to cone 2 the shrinkage was as much as 50% expressed in terms of the dry volume and the clay at this point reached the vitrified state showing a porosity of less than 1%. The color at this point was of a dark gray. The strength of the material in the dry state was very high, amounting to a modulus of rupture of 1100 pounds per square inch, which is considerably above the average. The material, therefore, has good plasticity but very high drying and burning shrinkage. Its refractory quality evidently is not of a high order."

CHAPTER IV.

WESTERN COALFIELD AND SOUTH CENTRAL KENTUCKY

The area described in this chapter includes that portion of the state extending from the Tennessee River on the west to the Bluegrass region in the northern half, and the eastern coalfield in the southern half of the state. It does not include the belt of lower Mississippian formations which surround the Bluegrass region, these for convenience being included in Chapter III.

The area under discussion embraces therefore the following formations:

1. Surface clays and loams of flood-plain or terrace character. These are found bordering streams, and are often suitable for the manufacture of common or even face brick and sometimes drain tile. The most important of these deposits are those located along the Ohio River, and which are worked at several points, notably Henderson, West Point, Uniontown, etc.

2. Allegheny series of shales found in the western coalfield. As a rule these are not always of great thickness and some may be too carbonaceous to use without trouble in firing. Some of them, as the tests given on subsequent pages show, are of the proper nature for use in the manufacture of brick, tile and hollow blocks, or in one case possibly even stoneware. None of those examined have been found to be of the fire-clay type.

Some of the shales, as around Madisonville, are used in their weathered condition.

The Allegheny formations of the western coalfield consist of a series of shales, sandstones, coals and some limestone. Structurally they form a basin, with the beds around the margin dipping towards the center.

3. Pottsville formation. This formation exhibits a "conglomeratic or coarse sandstone phase as a continuous border to

the western coal field, (Miller, Ref. 23, p. 155), except on its eastern side. Here there is a considerable stretch where no conglomerate occurs. There is an interesting outlier or rather long tongue-like projection of the lower conglomerate of the western field, which stretches in virtual continuity from the extreme eastern end of it through Hart County, and along the boundary of Larue and Green and Taylor counties as far as the top of Muldraugh's Hill, forming the boundary of Taylor and Marion counties north of Spurlington."

The conglomerate itself is of no value for the manufacture of clay products, but there are certain pockets of white clay, often referred to as "kaolin," which occur at the base of the Pottsville in Hart, Edmonson, Taylor and possibly other counties.

This material is undoubtedly of the same character as the so-called Indianaite which is found at the same geological horizon in Indiana, and which there is supposed to have been formed by the replacement of the Pottsville pebbly sandstone.

In Kentucky this material occurs immediately below the Pottsville, and at times contains partially disintegrated pebbles of the latter. When pure it is a white, dense, clay-like substance, with conchoidal fracture and resembling unglazed porcelain. Fragments of it exposed to the weather break down very slowly. It apparently never occurs in commercial quantities, and where found grades into or is mixed with colored clays which may represent a weathering product. At one point Gardner records the finding of a small amount of bauxite and wavellite with the "kaolin." We were able to find some of the wavellite but no bauxite, but as the test pit had caved in, no accurate observations were possible.

It is possible that some of the clay shales worked at Hawesville, Hancock County, are of Pottsville age.

4. The Mississippian rocks are represented by the Chester series and the Mammoth Cave limestone, as well as the narrow tongues of the Waverly series. The Chester series is found form-

ing an irregular belt surrounding the western coalfield. (Fig. 2.) Its subdivisions have been given by Butts, (Ref. 3), as follows:

Clore formation.
Palestine sandstone.
Menard limestone.
Tarr Springs sandstone.
Glen Dean limestone.
Hardinsburg sandstone.
Golconda formation.
Big Clifty sandstone.
Ridenhower shale.
Gasper oolite.
Bethel sandstone.
O'Hara limestone.

On the western side of the coalfield in Crittenden and Livingston counties the section is pretty complete, but on the eastern side from Breckinridge to Warren County the subdivisions above the Tar Springs sandstone are difficult to identify and Butts refers to them collectively as the Buffalo Wallow formation.

On the eastern side of the coalfield the Pottsville conglomerate rests unconformably on the Chester, the upper surface of the latter being very irregular due to erosion, so that the Pottsville does not always rest on the same member, erosion sometimes having removed beds as far down as the base of the Big Clifty. It is difficult indeed at times to say exactly what clay or shale is underlying the Pottsville.

The three formations that may be of interest to the clay worker are the Buffalo Wallow, Golconda and Ridenhower.

The Buffalo Wallow shales are used to make an excellent grade of roofing tile and floor tile at Cloverport. Shales or clays of this formation also occur in Hardin and Hart counties, some of them firing to a hard body of red color.

The Ridenhower shale is developed chiefly on the western side of the coalfield and is said to be rather sandy. A shale underlying the Big Clifty sandstone at Eastview, Hardin County, may belong to this formation.

The Golconda, according to Butts, carries 60 feet of shale which can be seen along the road to Brownsville.

All in the Chester formation is well worthy of further examination.

5. *Mammoth Cave Limestone.* These limestone formations underlie the larger part of the area referred to in this chapter. They are of no value to the clay worker in their fresh condition, but yield on weathering residual clays which can be used in the manufacture of common brick and sometimes possibly tile. Deposits large enough to support a small brick plant are abundant, but they are not likely to be used by larger plants, partly because better materials can be obtained in other parts of the area.

The counties referred to below are those in which clays were examined as regarding the clays of which other tests and descriptions have been published.

Barren County

Most of this county lacks transportation routes, but aside from this there is not much chance of finding anything better than residual clay for common brick.

The Dickinson Brick and Tile Company used to manufacture common brick at Glasgow, but is idle at present.

Breckinridge County

The Chester series of the Mississippian underlies a large part of Breckinridge County, and it thus forms excellent territory to prospect for clays.

Murray Roofing Tile Company. At Cloverport in the northwestern corner of the county, the Buffalo Wallow shale (Fig. 13) is used by the Murray Tile Company for making an excellent grade of roofing tile, and quarry tile for flooring purposes.

Fig. 13. Shale bank, Murray Roofing Tile Company, Cloverport.

The shale is obtained from a pit immediately adjoining the works, and as it dips into the hill is overlain by limestone. The shale used is slightly weathered and in spots slightly calcareous as well as containing a little gypsum. It has excellent working qualities. The following represents a partial test of the material:

Plasticity	Excellent
Water of plasticity	23.4%
Modulus of rupture, lbs. per sq. in.	468
Air shrinkage, linear	7%
Color after firing	Red

The clay fires to a very hard body. If manganese is added to the material a brown tile is produced.

During the summer of 1921 a new pit was being opened up several hundred yards northeast of the works, and also along the railroad. This new pit also has a blue and a red shale, both of which may be used.

The shale after crushing and tempering is molded in a stiff-mud machine, the clay being run from the die as a ribbon which is then cut up into the proper lengths for shingle roofing tile or floor or roof quarry tile. Drying is done in tunnels. The plant is equipped with 6 circular down-draft kilns, 30 feet in diameter, and the firing takes 12 days. The tile are set in the kiln on edge, in pockets formed by quarry tile. The thermo-

electric pyrometer indicates 1750° F. as the temperature of firing, and this gives a good, hard product. The roofing tile weigh 1175 pounds per square.

A number of the extra thin quarry tile for flat roofs have been shipped to Cuba.

This factory when first established was producing paving blocks, and was later converted into a tile works.

Unworked Deposits. Little detailed work has been done on the Chester shales of Breckinridge County.

Easton (Ref. 10, p. 768), notes a 20-foot bed of shale at Buffalo Wallow, which he states is dark gray in color, of low

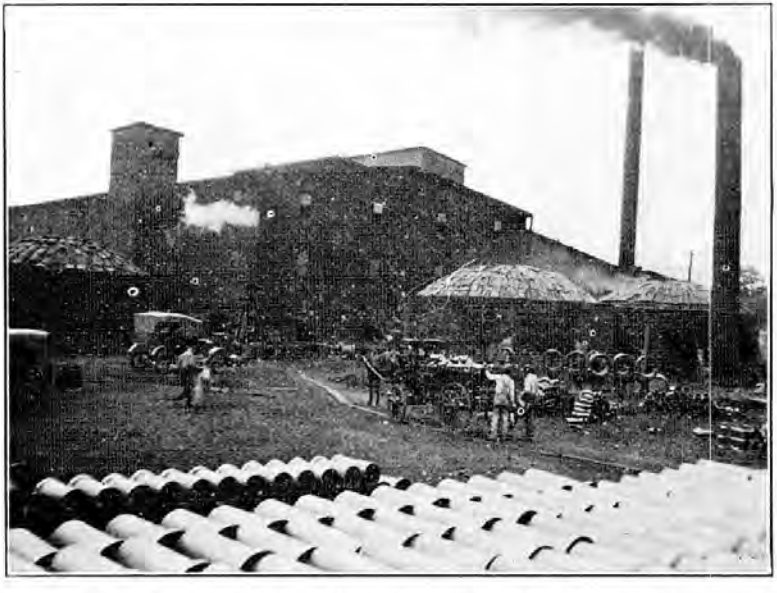


Fig. 14a. Factory of Owensboro Sewerpipe Company.

plasticity, and fires red. It has 7.5% air shrinkage; 10% fire shrinkage; vitrifies at cone 4, and becomes viscous at cone 6.

He also (Ref. 10, p. 767) refers to a 40-foot bed of Chester shale at Stephensport. This he states is also lean, and fires red. It has 5% air shrinkage; 5% fire shrinkage, and vitrifies at cone 2.

Crittenden County

Most of this county is underlain by Mississippian formations, especially limestones, which have yielded residual clays. These have been referred to by Fohs (Ref. 12, p. 124) in an earlier report of the Kentucky Geological Survey who calls them *laterites*.

Fohs also describes a siliceous clay, said to be of refractory quality, and similar to that found at the Stevens mine, (See under Livingston County), but these deposits known also as the Corn Mines have been inactive for a long time.

The Ridenhower shale although occurring in Crittenden County, shows few outcrops on account of its being a soft stratum between two sandstones, but according to Butts (Ref. 3), a good

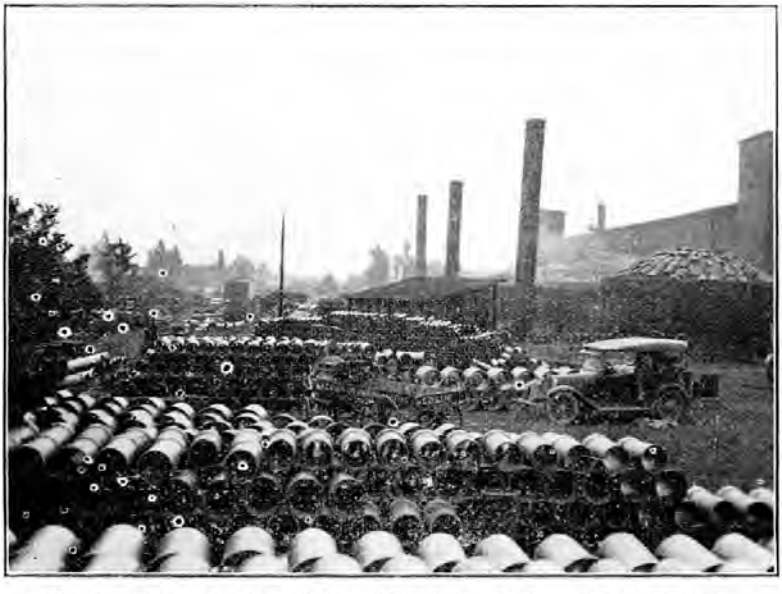


Fig. 14b. Stock yard and kilns of Owensboro Sewerpipe Company.

exposure of the shale in the condition of laminated clay is seen on the road to Siloam school, 3 miles west-southwest of Marion, where 50 feet of it is exposed.

Daviess County

This county is underlain entirely by Pennsylvanian formations, with the exception of a strip along the Ohio River, where

flood-plain deposits lie below the surface. Similar alluvial deposits are also found along some of the streams towards the interior of the county.

It would seem desirable to prospect this county for shales in the Pennsylvanian. Beds of red-burning shale for example can be seen outcropping in places along the river, although there is some question regarding their thickness. Shale suitable for sewer pipe is also said to occur near Short's station.

Owensboro. Two sewer-pipe and flue-lining plants, both belonging to the Owensboro Sewer Pipe Company, are located at Owensboro, but only the larger one was in operation in the summer of 1921.

This company obtains a clay shale from Lamkin, Hancock County, and a shale of Pottsville (?) age from Hawesville, Hancock County. Both of these underlie coal and are regarded as low-grade fire clays. The flue linings are made of the Lamkin clay, while the Hawesville shale alone is used for small size sewer pipe, but not for large ones as it is said to cause blistering. Hence the large pipe are made of a mixture of the two clays.

The following tests are of importance as showing the character of the clay found in the Pennsylvanian of Hancock County.

Shale from Hawesville (Lab. No. 2432).

Lime carbonate	None
Plasticity	Good
Water of plasticity	16%
Slaking time	30 minutes
Modulus of rupture, lbs. per sq. in.	196
Air shrinkage (linear)	35
Color after firing	Buff
Steel hard	950° C.

	Fire Shrinkage	Absorption	Porosity
	%	%	%
950° C.	1.5	9.3	27.9
1050° C.	2.0	9.8	25.1
1070° C.	3.0	8.2	.....
1130° C.	3.5	8.2	21.0
1230° C.	4 5	2.3	4.6
1310° C.	5.	.8	3.0
1430° C.	0. Overfired.		

The air shrinkage of the clay is low, and it requires little water to mold. The modulus of rupture is good and color after firing good. It has a good firing range, but is not a true fire clay.

It is used for sewer pipe and flue linings, and could also be used for face brick and terra cotta.

Clay shale from Lamkin (Lab. No. 2433).

Lime carbonate	None
Working qualities	Smooth
Plasticity	Excellent
Water of plasticity	11.6%
Modulus of rupture, lbs. per sq. in.	199
Air shrinkage (linear)	3.5%
Color after firing	Buff
Steel hard	950° C.

	Fire Shrinkage	Absorption	Porosity
	%	%	%
950° C.	1.0	14.2	27.9
1050° C.	2.0	10.1	27.0
1070° C.	3.0	7.9	21.0
1190° C.	4.5	6.7	20.4
1310° C	6.0	.5	2.0
1430° C.	Overfired.		

It is an excellent clay for the use to which it is put. It is not quite as dense burning at the lower temperatures as the Hawesville material. Its air shrinkage is low, working qualities good and modulus of rupture also good.

In addition to being used for sewer pipe and flue linings this clay should also find use in the manufacture of face brick and terra cotta.

The clay and shale are brought to the plant over the Illinois Central Railroad. The material is first crushed in a dry pan, screened and then tempered in wet pans, after which it is delivered to the pipe press.

Drying is done on floors, and firing in circular down-draft kilns of which there are 10. It is said to take 3½ days to reach a temperature of 1800°F. as indicated by the pyrometer. The kilns are salted when 1850°F. is reached. Trial pieces are used in addition to the pyrometer.

The plant now running has a capacity of 3000 8-inch sewer pipes per day.

The product is shipped to different cities between New Orleans and Cincinnati.

One common brick works is in operation here, that of S. B. McCullough, which is located one mile south of Owensboro. The material used is a sandy alluvial clay, lying in the Ohio flood-plain. The product consists of common brick, molded by the soft-mud process. A stiff-mud machine was being installed during the summer of 1921.

The Tennes Brick Company formerly in operation at Owensboro, is no longer running.

Moseleyville. At Moseleyville, 10 miles south of Owensboro, the Clark Manufacturing Company operates a drain-tile plant. The clay underlies flat land bordering a stream and is undoubtedly an alluvial deposit. The pit which lies near the plant shows an upper loamy clay that has been mined to a depth of 8 to 10 feet, while under this there is a distinctly bedded clay of bluish color, and at least 3 feet thick. Many small concretions of lime carbonate occur in the upper clay, but they seem to lie mostly in a zone 3-4 feet below the surface.

The plant is equipped with a stiff-mud machine, two-story drying sheds, and three circular down-draft kilns, in which the ware is fired to 1750°F. The clay seems to make an excellent drain tile.

This company operates another plant at Ashbyburg.

Edmonson County

The southern portion of the county offers only residual red-burning clays derived from limestones, but the northern half is underlain by the beds of the Chester series and hence should offer good ground for prospecting.

Brownsville. Along the road leading from the Dixie Highway northward to Brownsville, there are sufficient shallow exposures of shale to warrant testing out this area with some care, and Butts (Ref. 3, p. 91) remarks that the Golconda shale along this road has a thickness of 60 feet.

Gardner (Ref. 13, p. 49) has called attention to several localities in this county; but they are either too remotely located from lines of transportation or of no commercial value.

He refers among others to two occurrences of the so-called kaolin, which is the same as the Indianaite of Indiana. One of these deposits is located on the John T. B. Stice place, 1½ miles in an air line southeast of Brownsville, and on the east bank of the Green River.

The section given by Gardner is:

Pottsville Conglomerate and sandstone	70 ft.
White particles	1 ft.
Yellow and waxy Indianaite	4 ft.
Mixture of bauxite and wavellite	2 ft.
Covered	10 ft.
Chester limestone	2 ft.

He says: "This material is stained with iron oxide to some extent on the outside of the pieces." The Indianaite is found in pieces from the size of a bird's egg to six inches diameter. The mixture of bauxite and wavellite occurs in chunks or boulders from 6 inches to a foot thick.

Analyses are given of: I. The white material at the top. II. The waxy material; and III. The hard brownish material at the bottom.

	I.	II.	III.
Silica	42.40	42.42	20.04
Alumina	36.21	35.20	40.53
Ferric oxide	.45	.64	1.24
Lime	.38	.34	.34
Magnesia	.53	.53	.40
Potash	.09	.23	.31
Soda	.08	.09	.....
Phosphorus pentoxide	.20	.22	3.75
Titanic oxide	tr.	tr.	tr.
Sulphur trioxide	tr.	tr.	.27
Ignition	14.52	13.84	20.92
Moisture	5.15	6.84	13.65
	100.01	100.35	101.47

Analyses I and II are evidently the same material. They contain too much chemically combined water for kaolinite. They also appear to have lost considerable weight when heated at a low temperature, as is characteristic of Indianaite.

The third analysis is rather peculiar. Dr. Peters refers to it as being possibly a miture of wavellite and bauxite. If so it must contain considerable free silica in addition, as neither bauxite nor wavellite normally carry any. It may be a mixture of bauxite, wavellite, and Indianaite.

Mr. Stice showed us the pit where the section given above was found, but it had caved in so that we were not able to see much. However, in the upper part of the deposit the lumps of Indianaite were to be found, and on the dump pile we found some specimens that appeared to be hard Indianaite with some stellate groups of acicular crystals that resembled wavellite. The occurrence is of undoubted scientific interest, but it is not of commercial importance.

On the north side of the Green River, along the road leading up the hill from the Brownsville ferry there are exposures of soft shale, but the outcrops were not sufficient to permit getting a fair sample for testing. They would undoubtedly bear prospecting.

On the W. B. Parsley place, 5 miles northeast of Brownsville, Gardner has noted a clay shale, at least 3½ feet thick, which was struck in digging a ditch. It may belong to the Chester shales. The material fires to a buff color, has 80 pounds tensile strength, 5% air shrinkage, and 12% fire shrinkage. It is not vitrified at cone 9. An analysis which is given shows 1.39% ferric oxide, and 4.53% total fluxes.

Grayson County

Gardner (Ref. 13, p. 61) notes that over the northeastern and eastern portions of the county the lowlands show exposures of St. Louis limestone, but that the uplands show exposures of rocks of the Chester series, while the higher hills are capped with the Pottsville conglomerate.

Of three occurrences of clay noted by him, none seem to be of commercial value either because of thick hard rock overburden, or because of their non-plastic character.

The Illinois Central Railroad crosses the county and it is probable that prospecting within shipping distance of this would show some suitable clays either in the Chester or in the Pennsylvanian.

Hardin County

Clay-bearing Formations. The clays of Hardin County have already been referred to in an earlier report by Gardner. (Ref. 13, p. 20.) As he there points out practically the only clays to be found in the eastern half are those resulting from the decay of limestone, and which could be used for making common brick. In case the clay is derived from a cherty limestone, care should be taken to remove or crush this material before the clay goes into the brick machine.

In the western half of the county clays or shales of Chester age occur. The clays are probably in some cases at least, shales which have been mellowed by weathering, and may harden as they are dug into.

Attention should be called to the fact that the clays in some cases overlie the Big Clifty sandstone, while in others they underlie it stratigraphically. When the latter is the case it would not pay to mine the clay by underground methods, unless it were a fire clay, and so far as is known no fire clays have been found in the Chester series in this county. There are places, however, where the Big Clifty sandstone has been removed by erosion or else where the slope in which the clay is exposed is a very gentle one, thus making it possible to dig quite a tonnage of clay without removing much overburden.

It must be confessed that all of the clays referred to by Gardner or of which samples were collected for testing for this report, are not located very close to the railroad, but in order to get exposures where samples could be collected so as to determine the character of the Chester clays in this county, it was necessary at times to go a little distance from the main lines of transportation.

Mr. Gardner suggests uses for the several deposits which he notes, but it is not known whether this is based on any tests that have been made, for none are given in the report. Some of these localities were also visited during the field work for the present report and some samples collected for testing.

Stephensburg. Gardner reports that on the J. B. Jenkins place, adjoining that of and owned by W. S. Glasscock, 1 1-4 miles south of Stephensburg on the Illinois Central Railroad,

the clay outcrops on a high ridge at the southern part of the farm. He gives the section as:

Big Clifty sandstone.	
Yellow plastic clay	2 ft.
Drab plastic clay	14 ft.
Oolitic limestone	20 ft.

Unless the clay could be found at a point where there is little sandstone overburden, it would not be practicable to work it, unless it represents a high-grade clay.

A sample was collected during the summer of 1921 from the farm of W. S. Glasscock, 1 3-4 miles south of Stephensburg. This is a dark plastic clay 4 feet thick overlain by 5 feet of a reddish clay that looks like residual material. The clay shows a rather abundant stain of iron and manganese. The deposit evidently lies between the Big Clifty sandstone and St. Louis limestone.

The material is probably red burning but the deposit is of doubtful commercial value.

East View. Gardner notes the occurrence of drab or yellow plastic clays at several localities around East View as follows:

1. Taylor Jeffries place, 1½ miles north of East View. 15 feet of clay under 30 feet of sandstone.

2. Joseph Lilly place, 1 mile northwest of East View. 5 feet of clay under 20 feet sandstone.

3. S. H. Richardson place, 3½ miles northwest of East View. Clay only 4 feet thick under 80 feet of Big Clifty sandstone, and probably not a commercial proposition.

4. J. D. Barnes place, 2½ miles west of East View. Clay 6 feet thick with 1 foot parting of coal.

5. Illinois Central Railroad deposit. This is a deposit of gray plastic, smooth shale, exposed in the railroad cut a few hundred feet south of East View station. Not more than 5 feet of gray shale is exposed above the level of the tracks, and there is about 10 feet of Chester sandstone over it. The same shale also occurs on the farm of Mrs. John Hall. Gardner gives the thickness of the shale as 10 feet, but there is no exposure showing that much now.

It is said that some years ago a number of tons of this shale were shipped to P. Bannon & Company of Louisville, for use in sewer-pipe manufacture, but that they considered it too fusible for their use.

A sample of the material, (Lab. No. 2420), was collected for testing and the results are given below:

Texture	Excellent
Working character	Very smooth, good
Water of plasticity	35.5%
Slaking time	21 minutes
Average modulus of rupture	499 lbs. per sq. in.
Air shrinkage (linear)	9.5%
Color after firing	Red, becoming deeper with higher firing
Steel hard	950° C.

	Fire Shrinkage	Absorption
	%	%
950° C.	6.	6.3
1070° C.	7.0	1.7
1130° C.	8.5	0.0
1190° C.	6.5	.4
1270° C.	2.5	Overfired

The plasticity and modulus of rupture are high. The air shrinkage is too high to permit the shale being used alone, and it should be mixed with a leaner clay. The color is excellent, and the fire shrinkage is not excessive.

On account of its bonding qualities it should make a good material to use in a mixture for drain tile, roofing tile, sewer pipe and earthenware.

Wash Nichols Place. This is also known as the farm of Leslie Ashlock. This is 2 miles west of East View, and the clay is well exposed in a large gully along the roadside just west of the house. The section is:

Pottsville sandstone.	
Clay shale	4 ft
Dark plastic clay, with upper part containing concretions of siderite and manganese	10 ft.
Purplish clay	8 ft.
Dark clay (calcareous)	2 ft.
Dark red clay	2½ ft.
Shaly clay, gypsiferous	4 ft.
Covered	15 ft.

The location of the deposit is such that it could be worked along the face of the gentle slope on which it outcrops without the necessity of removing much overburden. Two beds were sampled for testing, and the partial tests of each are given below.

The red clay (Lab. No. 2421) which is calcareous is of fair plasticity, and fires to a good red color, becoming steel hard at 950°C. The linear air shrinkage is 6.5%. At 950°C. it fires to a good brick with 2.5% linear fire shrinkage and 5.6% absorption. At 1050°C. it fires to a deep red body with 5% linear fire shrinkage and 3.1% absorption.

The indications are that it is a good common brick clay and might possibly make drain tile also.

The gray clay (Lab. No. 2423), which is also calcareous, has good plasticity. The properties are: Air shrinkage (linear) 7.5%. At 1050°C. it had 5.5% fire shrinkage, and 2.2% absorption. It fires to a red brick, which is steel hard at 950°C. and should give a good brick at that temperature. It might also work for drain tile.

James Coogle Farm. This lies 1½ miles northeast of East View station, and on the east side of the Illinois Central Railroad. Clay exposures can be seen which lie between the Big Clifty sandstone and the St. Louis limestone, but they are not sufficiently extensive to indicate the quantity or thickness of the material. They do, however, indicate that there is probably a rather persistent bed of clay shale lying below the Big Clifty sandstone.

East View. The two following analyses of a greenish gray clay from the property of C. F. Swindler have been supplied by C. E. Bales:

	I.	II.
Silica	57.20	57.96
Alumina	24.06	23.82
Ferric oxide	5.42	5.90
Lime	1.12	1.14
Magnesia	1.02	1.04
Alkalies	1.60	1.68
Ingnition	9.58	8.44
	100.00	99.98

Sample No. 11 was fired to 2500°F. and found to be vitrified.

Summit. Sam Nelson and James Lesley Farms. These are 2 3/4 miles south of Summit on a county road, at a locality known as Buffalo Wallow.*

The section shows:

Soil	2 ft.
Gray shale	9 ft.
Limestone	....

The shale is dark gray, free from grit, but contains a small amount of limonite.

Farther up the gentle slope the Big Clifty sandstone outcrops. Considerable clay could be removed without having to strip off any sandstone.

The following tests show the character of this shale. (Lab. No. 2450):

Lime carbonate	Appreciable
Working quality	Good
Plasticity	Good
Water of plasticity	25.2%
Slaking time	6 minutes
Modulus of rupture, lbs. per sq. in.	154
Air shrinkage (linear)	3 5
Color after firing	Red
Steel hard	950° C.

	Fire Shrinkage	Absorption
	%	%
950° C.	2.5	15.2
1050° C.	4.	12.4
1150° C.	4.	11.7
1190° C.	3.5	8 9
1240° C.	Viscous	

This clay fires to a good red color, but is not very dense burning. It should make good brick and probably hollow blocks.

West Point. The plant of the West Point Brick Co. is located on the Illinois Central and the L. H. & St. L. R. R., on the southwestern edge of the town.

*This is not the same locality as that of the same name near Cloverport.

The company has twenty-two acres of clay land, and the clay is a flood-plain deposit of brownish color, containing scattered pebbles of chert and other material.

Fig. 15. Digging clay with steam shovel, West Point Brick Works, West Point.

The clay is excavated with a steam shovel, and hauled in tram cars up to the plant where it is passed through a roller disintegrator, and a pug mill. Molding is done in a stiff-mud side-cut machine, which also has an attachment on the die for making rough-texture brick.

The brick are dried in a tunnel drier, and then fired in circular down draft kilns, of which the company has six, each 32 feet in diameter. Firing takes about 8 to 9 days, and the temperature reached, as determined by the pyrometer, is between 1650° and 1700°F.

The products consist of common brick, and rough-texture brick, and these are marketed throughout the state.

Hart County

Clay-bearing Formations. This county contains some clays that are of considerable interest.

That portion of the county lying south of the Green River has little but residual clay derived from limestone.

North of the river there are formations of the Chester series consisting of clays and sandstones, while overlying these unconformably is the Pottsville conglomerate. The contact between the Pottsville and Chester is a very uneven surface of erosion, and in the Bonnieville region, east of the Louisville and Nashville Railroad, there is, as has been earlier pointed out by Gardner an area of several square miles where the Pottsville rests almost upon the St. Louis limestone.

The most interesting and also important of the clay deposits in Hart County are located in the Bonnieville area.

Gardner (Ref. 13) has noted a large number of localities, and the most promising ones were visited during the fieldwork on which this present report is based.

Mr. Gardner had the advantage of seeing sections in freshly dug test pits, but still the samples obtained in the summer of 1921 may be regarded as fairly representative.

There are certain generalities which can be made regarding the Hart County clays, based partly on our own observations and partly on Gardner's.

They all overlie the St. Louis limestone and in turn underlie the Pottsville conglomerate. The clay overlying the limestone is apparently a sedimentary deposit, of variable color, high plasticity, and sometimes banded.

In the upper part of this deposit there are found pockets of the dense white clay known as Indianaite, which may be mixed with colored clays, which occasionally show similar texture.

It is not quite clear how much of these materials Mr. Gardner includes under the name of kaolin. He applies it beyond doubt to the white Indianaite, and also seems to include certain stained clays which could not be called kaolin.

It is certainly significant that the white clay occurs in proximity to the Pottsville conglomerate and may represent a replacement of it, as is known to be the case in Indiana. A point which would seem to confirm this is a statement by Gardner, quoted by Easton (Ref. 10, p. 723) to the effect that the "white clay deposits feather out into the conglomerate as has been shown by exposures made in tunneling."

Gardner also states that this "kaolin" has been experimented with in the manufacture of whiteware, with excellent re-

sults. Be this as it may, none of the observations made in the summer of 1921 make us feel warranted in assuming that the white clay occurs in commercial quantities.

Bonnieville. The following localities were visited in the Bonnieville district:

John Goldsmith Property. On the land of John Goldsmith, 3½ miles southeast of Bonnieville, the so-called kaolin is exposed in a gully 400 yards southwest of the house. In texture it much resembles the Indianaite from Lawrence County, Indiana, but the colors are white, yellow and brown. There is also considerable limonite and manganese mixed through the clay in the form of lumps and bands. The clay where exposed is about 4 feet thick, and is overlain by about 4 feet of Pottsville conglomerate. It is probably not of commercial value.

This locality is about 1 mile north of the Mrs. J. B. Isaacs place and about 2 miles west of the Mrs. John B. Moss farm.

No sample was tested.

Mrs. J. B. Isaacs Property. This is located 4½ miles southeast of Bonnieville, and 2½ miles east of Dividing Ridge station on the Louisville and Nashville Railroad. The clay is exposed on the north side of the hill 400 yards south of the house.

The section shows:

Covered hillside with "float" boulders of Pottsville conglomerate	30 ft.
Gray clay with red specks	2.5 ft.
Light drab clay, of good plasticity	10 ft.
Covered	....

The St. Louis limestone may lie not far below but is not exposed. Excavation of the clay could not be carried very far into the hill without encountering considerable overburden.

A sample of the clay (Lab. No. 2406) tested showed it to be of non-calcareous nature and good plasticity. It has a linear air shrinkage of 8%, and fires to a red brick at 950°C. with 1.9% absorption. It fires too dense for common brick, but possibly could be used for drain tile if mixed with a more sandy clay. It is not a fire clay.

An analysis of the material given by Gardner shows 5.04% of ferric oxide, and 10.43% of fusible impurities.

S. J. Murray Place. This is located 3 miles southeast of Bonnieville.

Gardner also mentioned this locality and gave the section as:

	Ft.	In.
Soil	2	
Soil, sand, clay	3	
Stained kaolin	3	10
White kaolin	1	
Stained kaolin		10

There are some old test pits near Mr. Murray's house, and he reports that different parties have from time to time endeavored to work this material but without success. He further states that one of the test pits showed 6 feet of kaolin with 12 feet overburden, in another 7 feet overburden, and in still another 15 feet. The clay, Mr. Murray states, changed constantly in color in all the test holes, being white, brown, yellow, purple, pink, etc. In places the clay also shows what appears to be a manganese stain.

It is true that some parts of the deposit as pointed out by Gardner from a chemical analysis will run low in iron oxide, but the deposit as a whole, can hardly be regarded as suited for the manufacture of any high-grade products.

James Riggs Place. Mr. Riggs' farm is located 4 miles west of Bonnieville, and the clays are exposed in gullies east of his house.

The clay here lies just above what is probably the Big Clifty sandstone, the section exposed in the hill slope showing.

Soil containing pebbles from the Pottsville	
Drab clay	10 ft.
Chester sandstone	8 ft.
Covered	3 ft.
St. Louis limestone	20 ft.

This is apparently the deposit to which Gardner assigned a thickness of 15 feet (Ref. 13, p. 41), but at present only 10 feet can be seen. The sandstone, below the clay, and now exposed, is presumably in that part of his section marked as "Covered."

The upper part of the exposed clay resembles the "kaolin" of this region, and again lies just below the Pottsville conglomer-

ate. It is, however, a little more plastic than the "kaolin" found at other points. The greater thickness of the clay here may be due to its representing a thicker bed lying at a lower horizon than that seen at other places under the Pottsville.

The clay, which is drab colored and fairly uniform in shade, is not being used. The following partial tests give an idea of the physical characters of the material (Lab. No. 2412) from the upper part of the deposit.

It is a clay of good plasticity, and non-calcerous character, which has a linear air shrinkage of 7.5 per cent. It fires to a steel hard, red brick at 950°C., with a fire shrinkage of 7.5 per cent, and 1.% absorption. This shrinkage is a little high for this low temperature. At 1050°C. the shrinkage is about the same and the absorption .7%.

The clay could probably be used for common brick, drain-tile or possibly even common red earthenware, but a clay of lower fire shrinkage should be mixed with it.

A second sample (Lab. No. 2413) from the lower part of the deposit, was also subjected to a partial test. It is a very smooth, non-calcareous clay of excellent plasticity. The clay has an air shrinkage of 7%, and at 950°C. fires to a steel hard, red body with 6.5% fire shrinkage and 2.2% absorption. Its fire shrinkage is a little high, and it should be mixed with a clay of lower shrinkage.

It could probably be used for drain tile, and common red earthenware.

J. Caswell Place. Four miles east of Bounieville at Highland's Mill there are extensive lenses of clay lying above the St. Louis limestone on Mr. Caswell's farm. The clay varies in color from drab to yellow and red, and contains limonite concretions as well as being stained with manganese. Several years ago a pit 10 feet deep was sunk in the clay without reaching bottom.

No sample of this was tested, but it is probably a red-burning clay.

Rosa Highbaugh Place. This property adjoins the preceding Caswell property, and on the former place, about 200 yards from Mr. Caswell's house, the same type of clay as described above outcrops.

There is at least 10 feet of clay exposed in a gully which furrows the gentle hill slope. The St. Louis limestone outcrops at the base of the hill, while above the clay is found disintegrated Pottsville material, so that the Chester sandstone is apparently absent. A considerable quantity of clay could be removed without having to strip off much overburden, but the deposit is unfortunately rather far from the railroad.

The clay is red, very dense and tough, and contains scattered stains of manganese. A few specimens of a cup coral Zaphrentis were found in it. The following tests were made on this material (Lab. No. 2422):

Lime carbonate	None
Working qualities	Good
Plasticity	Good
Water of plasticity	37.1%
Modulus of rupture, lbs. per sq. in.	509
Air shrinkage, linear	9%
Color after firing	Red
Steel hard	950° C.

	Fire Shrinkage	Absorption
	%	%
950° C.	6.5	4.5
1050° C.	7.5	2.1

The clay burns to good color. Its shrinkage is somewhat high, and it should be mixed with a more sandy clay. As it has a high modulus of rupture it could stand the addition of such a clay.

It represents a type that could be used for brick, tile or hollow blocks.

Similar clay is said to occur on the farms of W. Cruse and W. W. Thorp.

Pleas Lively Farm. About 1 1/4 miles southeast of Bonnieville on the Pleas Lively farm there is a good exposure of clay in the road cut. The section does not show a very thick deposit, although boring may prove a larger quantity than appears on the surface. It is:

Red clay, apparently residual	5 ft.
Yellow gray shaly clay	5 ft.
Sandstone	----

A few tests were made of this clay. (Lab. No. 2405.)

This is a smooth clay of good plasticity which fires to a red color. Additional properties are:

Linear air shrinkage		6.5%
Fire shrinkage	950° C.	.5%
	1050° C.	1.5%
Absorption	950° C.	14.3%
	1050° C.	11.7%

It is probable that this could be used for brick, tile and possibly common red earthenware.

Mrs. John Moss Place. This lies about 5 miles southeast of Bonnieville and is referred to in Gardner's report (Ref. 13, p. 31) as the Philip Moss place.

The test pit made here is now filled, but is said to be the first place where the "kaolin" was noticed in this region. Judging from the pieces picked up around the pit, the clay is some of the whitest that was found in this region, but the pure white material was only 1 foot thick, according to local reports, and hence did not occur in commercial quantities.

Below the white material were clays of all colors and these have also been referred to as kaolins, although they are not properly to be classed as such. A bed of coal was found below the clay.

These clays lie just below the Pottsville conglomerate, while in a hollow below the old pit is an outcrop of sandstone about 40 feet thick, which is probably of Chester age.

Some 15 or 20 years ago some tunnels were driven into the hill below the conglomerate and about 3 carloads of clay are said to have been shipped from them.

It will be of interest in this connection to quote two analyses of the white clay which are given by Gardner (Ref. 13, p. 32):

	I.	II.
Silica	48.09	42.32
Alumina	34.66	36.92
Ferric oxide	.78	.62
Lime	.27	.21
Magnesia	.23	.08
Potash	.74	.47
Soda	.30	.18
Titanic oxide	.25	tr.
Ignition	12.68	16.69
Moisture	2.39	2.71

The second one of these shows a much higher percentage of loss on ignition than kaolinite would, and it is probable that some other hydrated aluminum silicate is present.

J. W. Priddy Place. Five miles west of Bonnieville is a hill known as Priddy's Knob, which is the second highest elevation in the county, and is capped with Pottsville conglomerate.

Here on the farm of J. H. Priddy, which lies between the old W. G. W. Butler place (to be described below) and that of James Riggs, previously mentioned, there are found three different clay horizons.

Beginning with the St. Louis limestone at the bottom, there follows next above a bed of plastic clay, which is in turn covered by Chester sandstone. Although it appears to be 10 feet thick, it is not a fire clay, and so it would hardly pay to work it. The Chester sandstone is at least 50 feet thick. On top of it there is exposed on the hill slope 10 feet of drab plastic clay with red specks, and which in appearance is very similar to a clay occurring at the corresponding horizon at the top of a hill on the Butler place. Above this clay the section for 20 feet is covered by wash material, which is topped by 5 feet of "kaolin" lying just below the conglomerate. It is quite impure here and contains much iron and manganese.

A partial test was made of the upper and lower portions of the 10-foot bed of clay above the Chester sandstone. Lower part of clay (Lab. No. 2414). This is a very smooth, non-calcareous gray clay of excellent plasticity. It has an air shrinkage of 7% and at 950°C. fires to a steel-hard body of good red color with an absorption of 1.7% and a fire shrinkage of 3.5%. It would in fact probably make a saleable product at even a somewhat lower temperature. At 1050°C. the clay shows a fire shrinkage of 3.5%, 1.5% absorption and deep red color.

This type of clay could be used for brick, hollow blocks or drain tile.

Upper part of clay, (Lab. No. 2415.) This clay is non-calcareous and of good plasticity. Its air shrinkage is rather high, viz. 10%, and it should be mixed with a more sandy clay. At 950°C. it fires to a steel-hard brick of good red color, 4.5% fire shrinkage, and 6.9% absorption.

It could be used in making brick, draintile, hollow blocks or common red earthenware, but not alone.

J. W. Priddy Place. This lies 6 miles southwest of Bonnieville and 8 miles southwest of Upton at what was referred to as the W. G. W. Butler place by Gardner. (Ref. 13, p. 45.) Since the date of Gardner's report the farm has been divided, Mr. J. W. Priddy now having the north section of the old Butler place, and Mrs. Louisa Priddy the south section. Gardner's observations were made on the latter half, on the hillside south of the old drain, but this is now covered by wash.

The clay beds at present can be studied in a ravine, on its north side, 400 yards east of the Lone Star schoolhouse, and 150 yards east of J. W. Priddy's new house the clays outcrop essentially as given in Gardner's report, which is:

Chester sandstone	20 ft.
Drab, plastic clay	10 ft.
White sandy shale	2 ft.
Big Clifty sandstone	75 ft.
Drab plastic clay	10 ft.
White sandy shale	2 ft.
St. Louis limestone	6 ft.

The plastic clays which overlie the St. Louis limestone do not run very uniform, and moreover the clay could not very well be worked because of the heavy overburden of sandstone.

Above the sandstone is another clay bed which is better exposed and more extensive. This is a gray plastic clay which is at least 10 feet thick, and which is separated from the sandstone by about 2 feet of white siliceous shale. The slope for about 20 feet above this clay is covered, but above this there are indications of more gray clay, which has lumps and streaks of a brown plastic clay in it.

A partial test of the upper clay bed shows that the material (Lab. No. 2404) is non-calcareous and has good plasticity. It has a linear air shrinkage of 8.5 per cent. It fires to a light red or pink brick, with only 1% fire shrinkage at 950°C. and 1050°C. The absorption at the lower temperature is 13.1 per cent and at the higher temperature 10.8%.

It is to be classed as a brick clay but should be mixed with a more sandy material. Further tests might demonstrate that it might be useful for other purposes.

The deposit is located rather far from the railroad.

Henderson County

This county is underlain by Pennsylvanian formations, with the exception of a strip bordering the Ohio River along the northern margin of the county. This strip is underlain by flood-plain deposits which are utilized in the manufacture of brick and tile.

Clays Associated With Coal. Since many of the coals of the western coal field have shales or clays either above or below them, and since these materials associated with coals are sometimes of a refractory character, it is desirable to get all available information on this point.

Easton in an earlier report (Ref. 10, pp. 843-846) has given some partial data from several localities in this county, although in most cases he does not appear to include figures showing the thickness of the bed. These are:

Baskett. Pittsburg Coal Company. Baskett Mine. A dark gray clay 3 to 3½ feet thick underlying the coal. It is soft, plastic, and has 5% air shrinkage. The tensile strength is 84 pounds per square inch. It fires to a yellow color. The clay is said to have puffed up when fired at cone 1, but this was probably due to its being fired too rapidly. It contains both carbonaceous matter and pyrite.

Bluff City. John Archbold Coal Company. A dark gray clay of good plasticity. It has 9% air shrinkage, 10 pounds per square inch tensile strength, and fires to a red-brown color. Unless slowly fired it will puff up in burning. It is not a refractory clay, but is probably to be classed as a brick clay.

Smith's Mills. Smith Mills Mine. A dark bluish plastic clay underlying the coal. It has 8% air shrinkage, 63 pounds per square inch tensile strength, and fires to a yellow color. It swelled at cone 1, hence would have to be slowly and properly heated to prevent this.

Spottsville. Green River Coal Company, Spottsville Mine. Clay under No. 9 coal, with an average thickness of 4 feet, and

a range of 18 inches to 6 feet. This is a dark gray, plastic clay, with 6% air shrinkage, and 72 pounds per square inch tensile strength. It fires to a yellow color, but swelled and cracked in the operation.

Brick and Tile Industry. The two active clay-working plants of Henderson County are both located at Henderson, and operated by Kleymeyer and Klutey. This firm has a brick and tile works 1 mile southwest of Henderson, the plant having been established in 1880. The product is drain tile.

Clay is obtained from an alluvial deposit a short distance from the works, and seems to run in pockets, the rest of the deposit being sand. Borings carried through the clay to a depth of 30 feet run into quicksand.

The clay is mixed in soak pits before putting it through the tile machine. The tile are dried on pallet racks, and firing is done in 3 circular down-draft kilns. The grates of the kilns are supplied with forced draft, the pressure being derived from an electrically driven fan, and the air distributed to the kilns through a 24-inch sewer pipe laid below the yard floor. Burning takes 3½ to 4½ days. The pipe shrinks 1¼ inches in 13.

The second plant of this firm is located on the southeastern edge of town, and the product consists of common brick.

Fig. 16. Brick kilns, Kleymeyer and Klutey, soft-mud plant, Henderson.

The clay pit is a shallow excavation on a gentle slope adjoining the works, and the clay has not been dug to a depth of over 4 feet. It is of a sandy nature, and at times shows an indistinct banding. The clay is mostly of a yellow color, slightly calcareous, and contains a number of lime carbonate concretions, which begin to be numerous at about 4 feet depth. The clay fires to a red color.

At the works it passes through rolls, soft-mud brick machine, tunnel driers, and then to rectangular kilns. There are

Fig. 17. Firing a brick kiln, Kleymeyer and Klutey, soft-mud brick plant, Henderson.

two Dutch kilns, which require about 12 days to fire, and are supplied with forced draft in the fire boxes. In addition there are two up-draft closed rectangular kilns, of 130,000 capacity each. These are said to fire in 7 days. Burning is checked with a thermoelectric pyrometer, and the temperature reaches 1800°-1900°F. The clay fires to a good red brick.

E. W. Suss formerly made brick at Baskett, but the yard has not been in operation for four years.

Hopkins County

The bed rock formations of Hopkins County are all of Pennsylvanian age, with alluvial deposits resting on them here and there, or with residual clays in places resting on the bed rock.

There would consequently seem to be four possible types of material to interest the clay worker, viz.: Alluvial clays, residual clays, Pennsylvanian red-burning clays, and fire clays also of Pennsylvanian age.

Alluvial Clays. No clays of this type are worked in the county. They may form local deposits along some of the streams, and more particularly along the Tradewater River.

Residual Clays. Some of the clays utilized by the clay plants of Madisonville might be regarded as of this nature, in that they probably represent mellowed shale deposits which have been softened by weathering. Otherwise no residual clays are worked in the county. They could probably be found at different points to supply small plants.

Pennsylvanian Shales. As the field work carried on during the summer was largely a reconnaissance, it was not possible to make a detailed examination of the coal measures of the western field, or even of Hopkins County. From what was seen, however, one feels that there is a possibility of finding some good shales in the county. Around Madisonville, for example, there were several good "showings," as described below, but thick sections were not always available.

Pontiac Mines. At the No. 9 mine of the Pontiac Coal Company, 4 miles south of Madisonville, there has recently been sunk a slope which crosses a series of shale beds overlying the No. 9 coal, and from which the following section was obtained:

Red residual clay	3 ft.
Red and yellow plastic clay	15 ft.
Smooth shale (called "soapstone")	4 ft.
Light gray shale with pebbly concretions	20 ft.
Black fossiliferous, pyritic, shale	2.5-3 ft.
No. 9 coal	4 ft.
Underclay	....

A sample (Lab. No. 2425) was taken of the 20 feet of shale above the pyritic bed, and tested with the following results:

Lime carbonate	None
Plasticity	Fair
Working character	Fair
Water of plasticity	10.9%

Slaking time	6 minutes
Average modulus of rupture, lbs. per sq. in.	77.4
Air shrinkage, linear	3%
Color after firing	Red
Steel hard	1000° C.

	Fire Shrinkage (Linear)	Absorption	Porosity
	%	%	%
950° C.	1.	11.4	26.5
1050° C.	3.	7.0	20.0
1070° C.	4.5	5.3	.....
1150° C.	7.0	3.7	.....
1190° C.	8.0	2.0	.....

The plasticity of the clay is sufficient to work it in a brick machine of the stiff-mud type. The air shrinkage is low and the clay fires to a good body. The fire shrinkage is low, and the absorption is not excessive. The transverse strength is not high.

This clay should make good common brick and probably hollow blocks. It is not a fire clay, as it is overfired at 1130°C. It might also work for paving brick.

A separate partial test was made of the plastic clay (Lab. No. 2416) noted in the upper part of the section given above, and which clay is probably shale that has been softened by weathering. There is some doubt as to the quantity of material available, but it could easily be mixed with the underlying shale.

Clay from above No. 9 coal, at Pontiac Mines, 4 miles south of Madisonville.

The clay is non-calcareous and of good plasticity. The air shrinkage is 7½. It fires to a steel-hard brick of good red color at 950°C. with 4% fire shrinkage, and 9% absorption. It could probably be used for common brick or hollow blocks.

At the No. 1 mine of the Pontiac Coal Co., a somewhat different bed of shale is exposed. Here at the entrance to the mine the section shows:

Unfortunately the mine was not in operation, and consequently we were not able to get a sample representing the full depth

Fig. 18. Entrance to mine of Pontiac Coal Company, south of Madisonville. Shows clay underlying No. 11 coal.

	Ft.	In.
Shale, very smooth	6-7	
Gypsum		3
No 12 coal	5	
Marl	1	
Limestone	3	
No. 11 coal	6	
Underclay, exposed	5-6	

Fig. 19. Strippings of coal beds, Madisonville. The limestone just above rails is limestone between No. 11 and 12 coals.

The whole series dips slightly, so that the underclay is best exposed in the sides of the cut at the entrance to the tunnel. There it presents the appearance of a light-gray soft shale, mottled with limonite stains. Whether it continues of this character in from the outcrop is not known, but at the exposure mentioned it looks like a very desirable material to work, and could be mined in connection with the coal. Moreover in the strip pits near Madisonville it could be easily obtained.

The following tests of this material (Lab. No. 2426) indicate that this material has some rather desirable characteristics:

Working qualities	Good
Lime carbonate	None
Plasticity	Very good
Water of Plasticity	17.7%
Slaking time	19 minutes
Average modulus rupture, lbs. per sq. in.	224
Air shrinkage, linear	8%
Color after firing	Red
Steel hard	950° C.

	Fire Shrinkage	Absorption
	%	%
950° C.	1.5	15.4
1050° C.	2.5	9.4
1070° C.	2.5	6.8
1170° C.	6.0	5.7
1190° C.	6.5	5.4
1250° C.	8.0	.6

The air shrinkage is a little high, but the plasticity and modulus of rupture good. Fire shrinkage not excessive. It should work for brick, hollow block or drain tile, and possibly paving brick. It is also worth trying for common stoneware. It is not a fire clay.

Stanley Coal Company. This company has a mine located 3/4 mile northwest of Morton's Gap, on the west side of the Louisville and Nashville Railroad. A tunnel has been driven on the No. 9 coal. The roof of the coal is a carbonaceous and siliceous shale, while below the coal is a 4-foot bed of gray shale. Unfortunately the mine was not in operation, and consequently we were not able to get a sample representing the full depth

of the deposit. That taken came from the upper foot, and may have been slightly weathered.

Such as it is represents a non-calcareous clay, of very smooth character, but containing numerous tiny mica scales. Its other properties are:

Plasticity	Good
Slaking time	19 minutes
Air shrinkage (linear)	5%
Color after firing, reddish buff, changes later to deep red.	
Steel hard	950° C.

	Fire Shrinkage	Absorption
	%	%
950° C.	1.5	10.9
1090° C.	5.0	3.3
1190° C.	5.5	5.3

The material is not refractory. If any quantity could be mined with the coal it might be used for common or face brick or drain tile.

Hart Coal Corporation. At the mine of this company 1 mile south of Madisonville there is a somewhat strong outcropping of a purplish clay shale in the railroad cut near the shaft. Nothing is known of the exact extent of the material as no borings were made, but some local engineers believe there is a considerable tonnage of it.

The material (Lab. No. 2427) is non-calcareous in character, and of good plasticity. It molds easily, and has a linear air shrinkage of 6%.

When fired it gives a nice reddish-buff brick at 950°C. which has 2% fire shrinkage and is steel hard, while at 1050°C. it is red, with 6.5% fire shrinkage and only 2.8% absorption.

The material could probably be used for common and face brick, hollow blocks and drain tile.

Fire Clays. No true fire clays were found among any of the samples examined from Hopkins County.

Hutchinson (Ref. 20) in describing the coals of Hopkins County refers to fire clays in several places, but offers no evidence to prove that they are really of refractory character.

Thus he states that they occur under coals Nos. 9, 10, 11, 12, 14, 15c and 15e. We found no evidence of their existence under coals 9, 11 and 12.

Brick and Tile Industry. There are two active clay plants located near Madisonville, one making brick, the other drain tile and hollow blocks.

W. L. Hall Plant. This is located in the southwest part of Madisonville, on the Louisville and Nashville Railroad coal switch. The product consists of common brick, face brick, and low-grade fire brick, which is sold chiefly to a local market. There are two pits which are in different parts of the same deposit. The material used is a partly weathered clay shale mostly of yellow and reddish color, while in the bottom of the pit the beds are harder, less weathered and of a bluish and red color.

One pit shows the following section:

	Ft.	In.
Soil		10
Brownish red clay	6	
Red sandy clay	1	6
Yellow clay	5	
Drab shaly clay	5	

Most of the clay fires to a red color, but bluish clay shale in the bottom of one pit fires to a buff color and is termed a fire clay.

In practice all of the clays except the "fire clay" are mixed together but the latter is dug separately.

The clay is gathered under a drying shed, crushed in a dry pan, screened and then molded in a dry-press machine. The bricks are fired in Dutch kilns. A sample of the so-called fire clay was examined and the material (Lab. No. 2429) was found to be calcareous in spots.

It is of excellent plasticity, but has a somewhat high linear air shrinkage of 9%. It fires to a buff color but is not a fire clay. It could be used for face brick but is not recommended for tile.

At 950°C. it gave 3.5% fire shrinkage and 9.2% absorption.

At 1050°C. the fire shrinkage was 4% and absorption 4.8%.

It would be advisable to mold it dry press instead of by a plastic process on account of its high air shrinkage.

Madison Drain Tile Company. This plant is located on the eastern edge of Madisonville. The product consists of hollow block and drain tile.

Fig. 20. Clay pit and plant, Madisonville Drain-Tile Company, Madisonville.

The deposit of clay, which adjoins the works is a weathered shale of Pennsylvanian age, and the section is as follows:

Soil	1 ft.
Clay	5 ft.
Gray clay shale	12 ft.
Sandstone	—

The clay is loosened up by a plow and then hauled to the plant by means of a scraper operated by a long cable. Only the 5-foot layer is used, the surface soil being first stripped off.

The clay is put through a rolls, and then a pugmill, after which it is molded in a stiff-mud machine. The ware is dried on racks under sheds, and firing is done in 2 circular down-draft kilns equipped with a thermo-electric pyrometer. About 48 hours are required for water smoking and 72 hours more to reach the finishing temperature of 1850°-1950°F. The ware is liable to develop a scum especially if set in the kiln too moist, but

careful drying eliminates most of this trouble. The clay fires to a good red color and the product is steel hard.

A partial test was made of the lower shale which is not used. The material (Lab. No. 2428) which is non-calcareous showed the following properties:

Plasticity	Excellent
Air shrinkage (linear)	7%
Color after firing	Red
Steel hard	950° C.

	Fire Shrinkage	Absorption
	%	%
950° C.	1.	11.7
1050° C.	7.	3.2
1150° C.	7.5	3.5

This appears like a clay that should work for red brick, drain tile or hollow block. It is not refractory.

Livingston County

This county contains residual clays derived from Mississippian rocks, which could be used for common brick. Flood plain clays may also occur under the flat terraces bordering the Ohio River, and represent the type used for common brick and drain tile.

Fohs refers (Ref. 12) to shales of light green and purple color, 2 3/4 miles southeast of Lola near the Livingston County line. They are said to be plastic and of non-calcareous character, but no data are given as to their extent or physical characters.

A deposit of historic rather than commercial interest at the present time is the Stevens fire clay mine which was operated a number of years ago by the Western Clay and Mining Co. of Kewanee, Ill. It is located on the border line between Livingston and Crittenden counties, 2 miles a little south of east from Salem.

The material is a siliceous residual clay which is said to occupy a fault fissure between limestone and quartzite. (Ref. 28)

At the present time the workings are inaccessible as nothing has been done there for some years.

Fohs has noted (Ref. 12) that within a radius of 3 miles of Smithland on the east side of the Cumberland River, there are exposures of hard siliceous fire clay, resting unconformably on Mississippian limestones, and capped by ferruginous sandstone and chert conglomerate. They are supposed to be a part of the Lafayette formation. No tests of the material are given, but it is said to have been formerly shipped to Illinois. The deposits do not appear to have been worked for a number of years.

Muhlenberg County

This county is underlain by coal-measures rock except a small piece in its southwestern corner where rocks of the Chester series occur.

Shales Associated With Coals. Samples of the shale or clay underlying the coal beds were collected from a number of mines in this county to determine whether any of them might be refractory. None proved to be of this character, but the few tests made on them showed that in many cases they could be used in the manufacture of structural clay products.

Central City. Gibraltar Coal Mining Company, located on Illinois Central Railroad, 1½ miles east of Central City, and working No. 9 coal. The under clay is a hard, dark gray, moderately gritty shale, containing leaf impressions, and having a thickness of 2½ feet. It is very similar to the under clay of No. 9 coal at the Madison Coal Company's Mine near Central City.

The following analysis of clay associated with the coal in the mine of the Frankel Coal Company, has been supplied by C. E. Bales:

Silica	61.24
Alumina	25.83
Ferric oxide	3.12
Lime	1.04
Magnesia	.14
Alkalies	.90
Ignition loss	7.76
	100.03

This is evidently not a refractory clay if the composition throughout is like that indicated by the above analysis.

Madison Coal Corporation, located on the Louisville and Nashville and the Illinois Central railroads. The No. 9 coal is being worked. The under clay is a hard, dark gray, slightly gritty shale, with leaf impressions and slickensides. It is 2½ feet thick. The material (Lab. No. 2452) is non-calcareous and carbonaceous. Its plasticity is rather low, and the linear air shrinkage 2.5%. It burns to a red color, and could be used for making common brick, but it would be necessary to fire it slowly between 800° and 900°C. in order to get rid of the carbon in the shale and prevent swelling and black coring.

At this same mine coal No. 11 is also worked. The underclay here is soft when wet and weathered, of dark gray color, and somewhat iron-stained. It is only 18 inches thick.

This material (Lab. No. 2451) is a non-calcareous shale, which develops only moderate plasticity when ground and mixed with water. It fires to a red color, and can only be regarded as a common-brick material.

Meran. Pacific Coal Mining Company, located 3 miles southwest of Central City on the Illinois Central Railroad and working No. 9 coal. The underclay which is 2-3 feet thick is a dark gray very hard, sandy shale, with limonite stains and small specks of muscovite mica. When exposed to the weather it changes to a pale green color and slakes to small scaly particles.

The material (Lab. No. 2453) is calcareous in character and grinds up with water to a very lean mass. It has 2.5% linear air shrinkage, and fires to a red but not to a very hard body at 950°C. It is not a very desirable material even for common brick, nor is it a fire clay.

Mercer. Mercer Coal Company, working No. 9 coal. The underclay is a dark gray, slightly gritty, hard shale, which gets soft and sticky when wet. It is evidently similar to the underclay of the Madison Coal Company of Central City. The miners use this clay to plaster up their stoves.

Gibraltar Coal Company, located along Illinois Central Railroad, and working No. 9 coal. The under clay, which is 4 feet thick, is dark gray, very hard and slightly gritty. When ground and wet it becomes quite plastic and is similar to the

same bed found under No. 9 coal at the Madison Coal Company's mine, Central City.

Brick Industry. The only brick plant in operation in Muhlenberg County is that of the Central City Brick Company, located ½ mile northeast of Central City on the Illinois Central Railroad. The product is dry-pressed brick for common use, and supplies a local market.

The clay is probably a residual deposit which shows a section of:

Soil	1-3 ft.
Yellow loam	3 ft.
Clay and angular rock fragments	.....

The loam contains small streaks of a whitish clay.

The clay, after stripping off the soil, is cut up by a disk harrow and then hauled in wagons to the plant. There it passes through rolls, screen and is then dry-pressed. Burning is done in two Dutch kilns and takes about 12 days. The brick are of a pale red color but steel-hard.

Ohio County

All of Ohio County is underlain by Pennsylvanian formations with the exception of a narrow tongue of Mississippian in the eastern part which follows the valley of the Rough River nearly half way across the county.

Gardner in his report on the Hartford quadrangle, (Ref. 3), states that clay deposits of three types occur, viz.: fire clay, clay shale and residual clay. No tests of these are given.

The same author remarks that at one time considerable fire clay was shipped from Horton to P. Bannon and Company in Louisville. It was mined 1½ miles east of town on the A. V. Thomson farm. None has been shipped for some years.

Clay shale is said to be common in the form of interstratified members of the coal measures, and those free from concretions are easily accessible, but no specific localities are listed.

Residual clay of use for common brick can be found, and it has from time to time been used locally.

In the general section given by Gardner there is indicated a 15-foot shale over coal 10, and plastic clays under the Schultz-

town, Beaverdam and Millsite coals, but no tests of these are given.

Several localities of clay are also quoted by Easton. (Ref. 10, p. 874.)

One of these is on the Powers Place at Narrows, on the Illinois Central Railroad between Owensboro and Horse Branch. The material is thought to be a partly weathered shale and is said to fire to a white color. Another sample from the same place fired to a creamy yellow.

Along Boards Switch, 3 miles southeast of Fordsville, a 6-foot bed of clay is noted as lying above the Mitchell limestone. It fires to a dark red color, is nearly vitrified at cone 01 and viscous at cone 6.

Gardner (Ref. 13, p. 217) notes a clay from Bald Knob Church, Caney precinct, on the Pinchico Road. It is said to lie 2 feet below a coal bed, but the thickness of the clay is not given. The analysis which he publishes indicates that the clay may be of a buff-burning color, although this can not be predicted with certainty. It is:

Silica	62.76
Alumina	26.42
Ferric oxide	1.58
Lime	.32
Magnesia	tr.
Potash	.91
Soda	.26
Ignition and moist	7.73
	99.98

Gardner also refers to a 4-foot bed of dark gray clay under the No. 9 coal at Coffman. No tests of this are given, but the chemical analysis suggests that it is red-burning and not refractory.

Taylor County

Gardner has referred (Ref. 13, p. 54) to the deposits of so-called kaolin along the border of Larue and Taylor counties. They all lie below the Pottsville and above the St. Louis limestone and are similar in their physical characters to those described from around Bonnieville. They lie too far from lines of transportation to be of much commercial value.

Residual clay from the St. Louis limestone occurs at a number of points and could be used for common brick if necessary. Easton (Ref. 10, p. 883) refers to one deposit on the J. T. Purvis place on the Campbellsville road, 1½ miles southeast of Hibernia. The material is described as having good plasticity, and firing to a red color. It has 5% air shrinkage, a tensile strength of 71.5 pounds per square inch, and a fire shrinkage of 7%. It vitrifies below cone 1 and is viscous at cone 6.

At Campbellsville there used to be a small brick plant located on the property purchased for the Russell Creek Academy. The material is a residual clay. This was used to make hand-molded brick. At the time some new school buildings were to be erected the authorities of the institution installed a soft-mud brick machine operated by a tractor. The bricks were fired in a scove kiln and then used in the new school buildings. The machinery is now for sale. The procedure is a common one in many regions, where clay is easily obtained and there is a temporary demand for brick.

Union County

This county is completely underlain by Pennsylvanian formations with the exception of a strip of alluvial deposits along its western and northern edge. These alluvial deposits are former sediments of the Ohio River. There is also a possibility of finding flood plain deposits along the Tradewater River, which forms the southwestern boundary of the county.

Little is known regarding shale formations in the coal measures as no detailed study has been made of these. The following data are available on this county:

Sturgis. The Quinwin Brick and Tile Company has a plant on the edge of town, the product being building brick and drain-tile. There are about 20 acres of clay land belonging to the plant. The clay pit which lies just south of the works shows a tough, jointed clay, about 12 feet deep. It resembles the Ohio River clay dug at Paducah and may represent a high terrace deposit of the Tradewater River. Borings have shown that the clays runs 30 feet deep. There is some difference between the top and bottom clay, for the lower part of the deposit has less

shrinkage, makes a good drain tile, but not as good colored a brick as the top clay.

The clay after being dug is carried up to the adjoining factory by a feeder, and then passes through a rolls and pugmill. Molding is done in a stiff-mud machine with a revolving cutter. The bricks are dried in tunnels and fired in circular down-draft kilns of which there are two. It takes 8 days to complete the firing, and according to the pyrometer a temperature of 1800°F. is reached. The clay makes an excellent product.

Below the No. 9 coal in the No. 2 mine of the west Kentucky Coal Company, is a non-calcareous shale, which develops fair plasticity when worked up with water. It has 3% linear air shrinkage, and at 950°C. fired to a red, steel-hard body. It could be used in the manufacture of brick, and possibly hollow blocks.

Uniontown. Alhorn and Waller have a drain tile works located on the flat land at the southwestern edge of the village. The clay is probably a portion of the alluvial deposit of the

Fig. 21. Circular downdraft kiln, drain-tile plant, Uniontown.

Ohio River. It shows a vertical jointing. The pit which is a shallow excavation lies about 250 yards west of the plant, and

the clay is hauled there by wagon. Lime pebbles are not uncommon in the clay.

The clay is put through rolls, and then discharged onto a short conveyor belt which carries it to the soakpit. It is then shoveled into a pugmill and passes from this to a stiff-mud machine. The tiles are dried on pallet racks. The plant is equipped with one circular and one rectangular kiln. The temperature of firing is not known. Drain tile up to 12 inches diameter are made.

Henshaw. The Henshaw Brick and Tile Company has been in operation here. Easton (Ref. 10, p. 884) states that they use a dark siliceous soil, which gives a bad brick because of the amount of lime carbonate in it. The clay has fair plasticity and fires to a red but rather porous brick.

Webster County

Webster County is entirely underlain by Pennsylvanian formations which should be prospected for shale deposits similar to those found around Madisonville, Hopkins County.

In addition it is bordered on the northeast by the Green River, and on the southwest by the Tradewater River, along both of which it may be possible to find flood-plain clays.

Sebree. U. S. Bishop and Sons are operating a plant two miles east of Sebree on the Green River. They manufacture drain tile, hollow block and a few common brick. The tile are often shipped by boat during high water, and floated out to the farms where they are to be used.

The clay is a flood-plain deposit in which the section is:

Soil	½ ft.
Yellow, red-burning clay	3 ft.
Black clay	1 ft.
Gray clay	30 ft.

(10 feet of it exposed.)

All of the clay is used after stripping off the soil. It is hauled to the stock shed first. When used it is put through rolls and pugmill before being fed to the stiff-mud machine. The ware is dried on pallet racks, and on the floors of a two-story drying shed, being left there from one to two weeks.

Firing is done in a 30-foot circular, down-draft kiln, and a second one is under construction. The firing requires about 5 days, and this is sufficient to give a good hard tile and hollow block.

The clay is liable to scum both in drying and burning, but the lower portion of the clay deposit causes more trouble in this respect than the upper part.

The clays in the pit are mixed, although the lower one fires to a light pink, and the upper one to a red. The latter is also more plastic and has a higher shrinkage. Scattered pebbles and a few large lumps of both limestone and chert occur in the clay, but most of these are thrown out in the mining.

Providence. The Providence Brick Company has a yard located along the Louisville & Nashville Railroad, about 3/4 mile east of town, the product of the same being common brick, made chiefly to supply a local market.

Fig. 22. Providence Brick Company, Providence.

The material is plowed, collected by scrapers, and hauled to the works, where it is crushed in a revolving disintegrator, screened and then molded in a dry-press machine. The bricks are fired in rectangular kilns, and the process requires 12-14 days. The clay burns to a pale red color, but makes a good brick.

Underclays of Coal Seams. A number of samples were collected from different coal mines in order to ascertain whether

any of them were of refractory character. None of them proved to be fire clays, but some burned to a good red body.

Providence, Wynn Coal Company, located 3/4 mile east of Providence on Louisville and Nashville Railroad. Working No. 11 coal, which has a limestone roof. The underclay is 3½ feet thick, of dark gray color, slightly gritty, and not very hard. It has a little iron stain. In its fresh condition the material is a slightly calcareous, carbonaceous clay of poor plasticity, which fires to a red color, and makes a fair brick. It stands in rather strong contrast to the sample obtained from under the same coal at the Pontiac mines south of Madisonville. Weathering would undoubtedly improve it.

Economy Mining Company, ½ mile north of Providence on a spur of the Louisville and Nashville Railroad. The clay below the No. 11 coal at this mine is 3 feet thick, moderately hard, slightly gritty and of dark gray color. It is evidently similar to the preceding.

Hunter Coal Company, Mine No. 2, located ½ mile southwest of Providence on the Illinois Central Railroad, and working No. 9 coal. The underlying material is a shale, 3½ feet thick, hard when fresh, dark gray in color, and slightly gritty. When weathered it is soft, and shows a few limonite stains, as well as having a slightly salty taste, due to soluble salts. It is 5 feet thick.

This material does not develop very good plasticity in its fresh condition, but could be improved by weathering. It fires to a good red, hard body at 950°C.

Highland Mining Company, located in the town of Providence, and on both the Louisville and Nashville and the Illinois Central Railroads. The material under the No. 11 coal, which this company is working is very similar to the preceding.

Clay. West Kentucky Coal Company, working No. 12 coal. In their No. 2 mine the under material is a very lean, carbonaceous shale, which is not to be recommended for the manufacture of clay products.

Wheatcroft. West Kentucky Coal Company, working No. 11 coal. In the No. 4 mine, the material under the coal is a shale which works up to a mass of fair plasticity. The linear air shrinkage is 3.5%. At 950°C. it fires to a red body which is

nearly steel hard and has 0% fire shrinkage. At 1050°C. the body is steel hard, with 1.5% fire shrinkage and 7.7% absorption. This material should make a good red brick, and could possibly be used also for hollow blocks.

CLIFTY CONSOLIDATED COAL COMPANY.

The following tests of a clay from mine No. 1 were supplied by C. E. Bales.

Clay from Mine No. 1.—Clifty Consolidated Coal Company, Clay, Webster Co., Ky.

Ignition loss	11.16%
Silica	58.05%
Iron oxide	4.07%
Alumina	23.09%
Lime	1.48%
Magnesia	0.26%
Soda—potash	1.68%
Sulphur trioxide	Undetermined
	99.79%

Black color, moderately gritty, slaked readily.
Thin veinlets of coal and some pyrite present.
Water required to make plastic mass 17%.
Plasticity, good.

Air shrinkage	½ inch to the foot
Fire shrinkage	? inch to the foot
Total	? (Swelled up)

Fusible before blowpipe.

When heated in a kiln to 2400° F. swelled a great deal and became completely vitrified. It is not a fire clay.

Clay from Mine No. 2.—Clifty Consolidated Coal Company, Clay, Webster Co., Ky.

Ignition loss	8.80%
Silica	57.24%
Iron oxide	5.12%
Alumina	25.96%
Lime	0.99%
Magnesia	0.30%
Soda—potash	1.70%
Sulphur trioxide	Undetermined
	100.11%

Black color, moderately gritty, slaked with difficulty.
Thin veinlets of coal and some pyrite present.
Water required to make plastic mass 16%.
Plasticity, good.

Air shrinkage	5/16 inch to the foot
Fire shrinkage	7/16 inch to the foot
Total	¾ inch to the foot

Fusible before blowpipe.

When heated in a kiln to 2400° F. it assumed a brown color and reached the state of incipient vitrification.
No good for fire brick.

Ashbyburg. The Clark Manufacturing Company has a plant located along the Green River at Ashbyburg, and is engaged in the manufacture of common brick, drain tile and hollow block. The market is somewhat local, and the product can be easily shipped by boat along the Green River.

The clay deposit which is of the flood-plain type shows the following section:

Soil	½ ft.
Gray plastic clay	35 ft.
Black sand.	

Only 10 feet of the clay is exposed, the total thickness having been determined by boring.

A mixture of the upper clay and soil is used, and the only visible impurities in the clay are small concretions of limonite which may get into the product.

After digging the clay is piled under drying sheds. It is subsequently passed through rolls and pugmill into the stiff-mud machine. Drying is done under sheds and requires from 4 to 10 days, according to the weather conditions. The plant is equipped with 3 circular down-draft kilns, 26 to 28 feet in diameter. It takes about 4 days to bring the kiln up to 1750°F. (as measured by thermo-electric pyrometer) and it is held at that temperature for 24 hours.

The lower clay is especially apt to develop a scum on the ware. Hollow blocks and common bricks are made entirely from the upper clay, but for drain tile the lower clay is mixed with the top. The clay fires to a hard product with a good ring.

CHAPTER V.

BLUEGRASS REGION AND ITS SURROUNDING BELT OF KNOBS

This chapter includes the territory of the Bluegrass region, and the surrounding rim or belt of territory, sometimes spoken of as the Knob country because of its peculiar topography.

Clay-bearing Formations. The formations which contain materials of value to the manufacturer of clay products are the following:

1. Surface clays of Pleistocene Age. These are represented by alluvial deposits, like those underlying the terraces along Ohio River, and which are worked at Maysville for the manufacture of building brick.

2. Tertiary clays, represented by isolated deposits of the Irvine formation in Madison County, and of value for making stoneware and art pottery.

3. Waverly shales, outcropping in a semicircle from Vanceburg to Louisville and containing several good red-burning shales such as the Rosewood, of Jefferson County, the New Providence shale which is of great extent, and the Bedford shale found only in the east side of the Bluegrass region.

One of these, the new Providence, is utilized in the manufacture of common brick, hollow blocks, drain tile, paving brick, and red earthenware. The others can also be used.

4. Devonian shales, as the Ohio formation, of value only where it has weathered to residual clay.

5. Silurian shales as the Estill and Lulbegrud, found on the east side of the Bluegrass area. These are smooth, plastic, red-burning shales which can be utilized for building brick, hollow blocks, drain tile and earthenware.

6. Ordovician shales, like the Eden formation opposite Cincinnati, and the residual clays derived from the Ordovician limestones. These are capable of being used for building brick.

Bath County

The western half of the county contains residual clays derived from Ordovician limestones which could be used for brick manufactures, but most of them are rather remote from lines of transportation by rail.

Estill Shales. Excellent exposures of Estill shales are found on the Bert Cornett farm, 3 miles south of Olympia. Here the barren knobs formed almost entirely of Estill shale, over 100 feet thick, cover probably 10 acres. They are close to a railroad track formerly used to connect with the iron mines of this district, and are excellently located to be worked. There is furthermore no overburden to be stripped off of the shale.

Farther north on the land owned by the Rose Run Iron Mining Company there are similar knobs of the same shale. It also outcrops on the property of W. M. McLaughton, 1 mile north of Olympia station. Here it is slightly weathered, and the Ohio shale, also weathered in places, outcrops farther up the hill.

The Estill shale is a very plastic, smooth, soft shale which works up nicely. Physical tests of it are given under Estill County in this chapter.

Foerste (Ref. 11, p. 33) states that at Salt Lick on the Chesapeake and Ohio Railway, a few miles west of Farmers, the Licking River Railway runs in a southeasterly direction. One mile east of Salt Lick and along the railway a section of the New Providence (Cuyahoga) shale 108 feet thick is exposed. It contains a few thin beds of sandstone, but they are not in sufficient quantity to cause much trouble. Underlying this shale there is 14½ feet of black Ohio shale, and 15 feet of Bedford shale.

At Caney's Switch there is 55½ feet of New Providence shale, but it is of very sandy nature, containing a number of sandstone beds.

At Olympia Springs, a hill 1/2 mile east of the town shows 47 feet of New Providence shale. It contains a little sandstone and some nodular ferruginous layers, but Foerste expresses the opinion that these could be easily thrown out.

Salt Lick. One mile south of Salt Lick is a new brick plant, operated by the W. M. Harrick Brick and Tile Company, which

is run in connection with a saw mill. The plant is located between Mud Lick and Salt Lick Creeks.

A light colored flood-plain clay is used and the section exposed is:

Surface clay (stripped)	2 ft.
Flood-plain clay	2 ft.

Both the common brick and drain tile which are manufactured here are molded in a stiff-mud machine. One kiln had been built and a second was under construction. Burning is done with wood and takes 5-6 days. The tile are made in 3 to 8-inch sizes.

Boyle County

Clay-bearing Formations. Most of Boyle County is underlain by limestones, the residual soil from which where thick enough, could be used in common-brick manufacture. In the southwestern part of the county there is an area underlain by shales of the New Providence formation, bordered on the north and east by the Ohio black shale.

The Ohio shale in its fresh condition is hard, black and slaty, so that it is of no value to the clay worker. Where it has weathered to a residual clay it can be used for common brick.

New Providence Shale. The New Providence shale is an excellent material for structural clay products, and when fine grained can be used for red earthenware.

It is well exposed in a hill known as Blue Knob, which lies ½ mile west of Junction City. This bare knob of shale, which is spoken of locally as the "volcano," probably because of its conical shape, shows 85 feet of the New Providence shale, below which is the black Ohio shale. The bottom of the New Providence shale contains concretions of phosphate of lime, but these are in such a thin zone that they would cause no trouble.

The location of the deposit in Blue Knob is such that it could be easily worked, and the product shipped either over the Queen and Crescent or the Louisville and Nashville Railroads, both of which pass through Junction City.

Fig. 23. New Providence shale bank, Blue Knob, near Junction City.

The following tests (Lab. No. 2437) show the physical character of the shale in Blue Knob:

Lime carbonate	None
Working qualities	Very good
Plasticity	Good
Water of plasticity	25.6%
Modulus of rupture, lbs. per sq. in.	309
Air shrinkage, linear	3.5%
Color after firing	Red
Steel hard	950° C.

	Fire Shrinkage	Absorption
	%	%
950° C.	4.5	11.0
1050° C.	5.0	10.0
1070° C.	6.0	3 2
1150° C.	8.0	.4
1190° C.	Overfired	Slightly swelled

The plasticity, shrinkage, modulus of rupture and firing qualities of the material are good.

This clay is of a type that should make good brick, or hollow block. It might also work for common red earthenware. It is similar to the clay used at Firebrick, Lewis County, for paving blocks.

Foerste (Ref. 11, p. 157) gives the following analysis of this shale:

Silica	62.44
Alumina	17.87
Ferric oxide	6.31
Lime	.18
Magnesia	1.18
Potash	3 52
Soda	.77
Titanic oxide	1.04
Sulphur trioxide	.19
Ignition loss	4.85
Moisture	1.35
	99.70

Bullitt County

Clay-bearing Formations. The western half of Bullitt County is underlain by Mississippian formations which are chiefly limestone, excepting a belt of New Providence shale which lies west of the Louisville and Nashville Railroad. In the northern part of the county there are some excellent exposures of the Rosewood shale, notably in the vicinity of Brooks. Here the entire section of the Rosewood shale is exposed on the east slope of a ridge lying about ½ mile west of Brooks, the different beds being seen along a road which has been cut over this knob.

The shale is moderately hard, and contains many concretions of iron carbonate (siderite), as well as some gypsum. About 70 feet from the top there are also some limestone layers. Towards the top of the section the shale becomes sandy, where it grades into the Holtsclaw sandstone, which here shows two beds of sandstone with shale between them.

While the shale occurs in great thickness it would probably be impracticable to quarry it without the concretions, and hence in testing a sample of it in the laboratory, the proper proportion of concretionary matter was included, but it was not as finely ground as the shale.

The tests which are given below represent the physical characters of the Rosewood shale, the sample (Lab. No. 2478) representing a mixture of the different beds which are exposed.

Lime carbonate	None
Working quality	Fair
Plasticity	Moderate
Water of plasticity	20.7%
Modulus of rupture, lbs. per sq. in.	78.6
Slaking time	11 minutes
Air shrinkage (linear)	2%
Color after firing	Red
Soluble salts	Present

	Fire Shrinkage	Absorption
	%	%
950° C.	1.	13.5
1050° C.	3.	9.9
1150° C.	4.5	8.4
1190° C.	Nearly overfired	

This is not as good material as the New Providence shale. It fires to a red body and could be used for common brick. It is of doubtful value for hollow blocks, and also shows a tendency to develop a scum in drying.

The material could, however, be easily worked and there is an abundance of it.

A sample of slightly weathered shale (Lab. No. 2473) from the property of Dr. Lindsey Morrison at Lebanon Junction, was sent in to the Geological Survey office and appears to resemble that found in the New Providence formation. It has good plasticity and a moderate air shrinkage of 4.5%. At 950°C. it fires to a good red color with 2% fire shrinkage, while at 1050°C. it fires reddish brown with 7% fire shrinkage and only 4.8% absorption.

It is the type of material that is used for making bricks and hollow blocks.

Campbell County

Clay-bearing Formations. The county is underlain entirely by Ordovician limestones, which may supply residual clays suitable for common-brick manufacture. There is also a possibility of finding flood-plain clays of use for brick and tile along

the Licking River. The Eden shales in the extreme northern part of the county might also serve for brick making.

The only clay working plant in the county is that of the Alhambra Tile Company, whose product is plain, embossed and dull finished enamel tile, terra vitrea and faience tiles. These are made of a mixture of clays obtained mostly from Kentucky and other states. The product bears an excellent reputation and is widely used for decorative work. The prominent pieces of work in which the product from this factory is used include: Y. M. C. A., Hotel and Clinic Building, Cleveland, O.; LeBland Machine Tool Co., Cincinnati, O.; Citizens Bank and Trust Co., Newport, Ky.

Carroll County

Carroll County is completely underlain by limestone formations which may supply residual clays. There is a narrow strip of flood-plain material along the Ohio River, which has been used for making common brick by the Carrollton Brick Company at Carrollton.

Clark County

Clay-bearing Formations. This county lies partly in the Bluegrass region and partly in the belt of knob hills. In the former part residual clays from Ordovician limestones might serve to supply local brick plants. In the latter plastic materials could be obtained from the Niagara shales (Estill and Lulbegrud) and from residual clays from the Ohio shale.

Easton (Ref. 10) has noted several localities in Clark County as follows:

1. Along the Indian Fields—Clay City road, 2 miles from Indian Fields are deposits of weathered Niagaran shale. The material is very plastic and fires to a dark red color. It has 138 pounds per square inch tensile strength, and an air shrinkage of 7%. Its vitrifying point is low, and it is nearly viscous at cone 6.

2. On the R. Kidd place, 3 miles north of Indian Fields, are more outcrops of Niagaran shale. The properties of this material are:

Plasticity	Fair
Air shrinkage (linear)	5%
Tensile strength, lbs. per sq. in.	88.3
Fire shrinkage	4%
Color after firing	Pale yellow
Cone of vitrification	9

The color of this material when fired may be due to a high content of lime.

3. Several exposures around Kiddville are noted but not specially described.

4. One mile west of Indian Fields, the properties given are:

Plasticity	High
Air shrinkage (linear)	7%
Fire shrinkage	7%
Color after firing	Dark red
Cone of vitrification	.03
Cone of viscosity	—5

A chemical analysis which is given shows:

Silica	58.48
Alumina	19.33
Ferric oxide	6.08
Ferrous oxide	1.01
Lime	.82
Magnesia	2.27
Potash	4.58
Soda	.89
Titanic oxide	.45
Ignition loss	5.41
Moisture	1.02

5. One mile west of Indian Fields. This is in the Estill shale division of the Niagaran. It fired dark brown and was vitrified at cone 6.

6. Four miles south of Indian Fields on the Morgan Eubank place. Here there is recorded a deposit of greenish Estill shale, 21½ feet thick, which is said to underlie over 100 acres. The physical properties given are:

Plasticity	Good
Air shrinkage (linear)	5%
Tensile strength, lbs. per sq. in.	105
Fire shrinkage	10%
Color after firing	Dark red
Cone of vitrification	.02
Cone of viscosity	6

7. Two and one-half miles east of Indian Fields, on Orlando Hensley place. This is residual clay from the Ohio shale. The physical properties recorded are:

Plasticity	Good
Air shrinkage	5%
Tensile strength, lbs. per sq. in.	58
Fire shrinkage	7%
Color after firing	Dark red
Cone of vitrification	7

A chemical analysis which is given of this material is interesting on account of the remarkably high percentage of ferric oxide which it contains. The analysis shows:

Silica	44.40
Alumina	11.35
Ferric oxide	24.69
Lime	.26
Magnesia	.38
Potash	1.99
Soda	.26
Titanic oxide	.75
Sulphur trioxide	.56
Phosporus Pentoxide	.13
Ignition	12.28
Moisture	3.04
	100.04

Estill County

Clay-bearing Formations. Estill County lies in the belt of the "Knobs," and the rock formations consist of irregular patches of Silurian, Devonian, and Mississippian. The first and last might supply good shales. The second would carry only the black Ohio shale, which as already noted is of no value in its unweathered form.

There is no clay-working industry in the county at present, although common brick were formerly made by J. S. Stephens at Irvine.

Irvine. Along White Oak Creek on the property of Alfred Gum, 1 mile west of Irvine, there are excellent exposures of Niagaran shales, in fact the entire Niagaran series is to be seen in many of the hills in this vicinity, extending from the Richmond at the bottom to the overlying Devonian rocks at the top.

One section measured on Mr. Gum's land showed:

Onondaga limestone	15 ft.
Estill shale	50 ft.
Waco limestone	2 ft.
Lulbegrud shale	15 ft.

The Onondaga limestone rests directly on the Niagaran shales. It is magnesian, sandy, and characterized by cherty lenses lying parallel with the bedding.

The Estill shale may at times be exposed for a considerable distance with little overburden. The 2-foot bed of fossiliferous Waco limestone separates the Estill shale from the Lulbegrud shale, but the two shales look much alike, although the former is more gypsiferous, and the hillside along its outcrop is strewn with numerous gypsum crystals. Where the Onondaga limestone outcrops above the Estill shale and weathers, the surface of the shale may be covered with chert fragments derived from the limestone.

Both shales weather to a smooth, light gray clay, but even in their unweathered condition they are smooth and fairly soft.

Two samples of shales were tested from the property of Mr. Gum.

The one (Lab. No. 2443), represents the Lulbegrud shale. It represents a very smooth, slightly calcareous, soft shale. The other properties are:

Plasticity	Very good
Water of plasticity	30.7%
Slaking time	33 minutes
Modulus of rupture, lbs. per sq. in.	343
Air shrinkage (linear)	6%
Steel hard	1050° C.
Color after firing	Red

Fire tests.

Temp.	Fire Shrinkage	Absorption
	%	%
950° C.	4.5	12.4
1050° C.	5.0	8.6
1070° C.	6.0	.17
1150° C.	6.5	.4
1190° C.	Overfired	

This is very nice clay which is very similar to the Estill shale with which it is closely associated, and which should be of value in manufacture of brick, hollow blocks and drain tile. The smooth portions of it could be used also for common red earthenware.

The sample of Estill (Lab. No. 2442) from the same property is present in large quantity. It contains rather numerous scattered gypsum grains. Its properties are:

Lime carbonate	Present
Working quality	Excellent
Plasticity	High
Water of plasticity	32.7%
Modulus of rupture, lbs. per sq. in.	474
Air shrinkage (linear)	7%
Color after firing	Red
Steel hard	950° C.

	Fire Shrinkage	Absorption
	%	%
950° C.	3.	9.
1050° C.	9.	1.3
1070° C.	9.	.7
1150° C.	9.5	.3
1190° C.	Overfired	

This is an excellent clay, and should compete with the New Providence shale, although it is somewhat less desirable on account of its higher shrinkage. The plasticity and transverse strength are good. It should be of use in the manufacture of brick, tile, hollow blocks and probably red earthenware as it is very smooth.

A 6-foot bed of Estill shale can be seen in the Louisville and Nashville Railroad cut in the western part of the town of Irvine, and while the deposit is not of workable character, because of

its thickness and overburden, it serves to show the nature of the material. The section is:

Ohio shale	3 ft.
Onondaga or Columbus limestone	10 ft.
Estill shale	6 ft.

The Ohio shale also outcrops in the hill west of the cut where it shows a thickness of at least 50 feet. As seen there it is the usual black, fissile shale. The residual clay from it where formed is brown and red, and not very smooth. It could be used for bricks.

The Estill shale weathers to a light gray, very plastic, smooth clay, but contains considerable gypsum.

Foerste (Ref. 11, p. 46) calls attention to the fact that at the eastern end of the town of Irvine there is a hill known as Minerva Mountain which shows a thick section ranging from Mississippian limestone on top to the Ohio shale at the bottom. The New Providence (Cuyahoga) shale which is included in this section shows about 130 feet of shales that might be suitable for making clay products, provided they can be found at a point where the overburden is not too heavy.

Panola. The following two analyses of Niagara shale are given by Foerste (Ref. 11, p. 148) and are of interest in showing how these shales may apparently vary. No. I is from the railroad cut east of Panola station. No. II is from a point 2 miles southwest of Panola, and is quite plastic. It fires to a cream color. This is probably due to an excessive amount of lime:

	I.	II.
Silica	54.33	42.30
Alumina	19.44	20.84
Ferric oxide	5.00	4.12
Lime	1.88	13.32
Magnesia	2.22	.461
Potash	5.15	2.387
Soda	.31	.351
Titanic oxide	.39	.....
Ignition	7.80	16.221
Moisture	2.20	.....
	98.72	100.000

Fayette County

Only residual clays derived from Ordovician limestones are to be found in this county. They may vary somewhat in their character, and if not properly chosen are likely to cause trouble from fragments of limestone.

They have been used for some years around Lexington for the manufacture of common brick, but at present the only plant in operation is that of the Lexington Brick Company. This is located east of town on the southside of the Liberty pike. The material being used is a residual clay that is said to run 4 feet deep, and as the bed rock is somewhat slabby in character, pieces of it are likely to get into the clay.

The clay after digging is put through a rolls, pugmill, and soft-mud brick machine. The bricks are dried on pallets and fired in Dutch kilns. The clay fires to a good red color.

Grant County

This county is underlain by Ordovician limestones, which may yield residual clay, but there are no clay-working plants in the county.

Easton (Ref. 10, p. 803) has referred to a yellow calcareous shale which occurs in the first railroad cut north of Mason. He gives no data regarding its thickness, but notes that it has the following physical properties.

Plasticity	Good
Air shrinkage	8%
Tensile strength, lbs. per sq. in.	74
Fire shrinkage	5%
Cone of vitrification	.01
Cone of viscosity	5

The following analysis of it is also given by him:

Silica	52.50
Alumina	16.87
Ferric oxide	5.28
Ferrous oxide	1.01
Lime	3.04
Magnesia	2.06
Potash	5.67
Soda	1.44
Titanic oxide	.50
Phosphorus pentoxide	.33
Water and carbon dioxide	9.01
Moisture	2.00
	99.71

Jefferson County

This county is in some respects the most important one in Kentucky so far as the clay-working industry is concerned, partly because it contains extensive deposits of excellent clays, and partly because of the diversity of character of the products manufactured here, these including common and face brick, hollow blocks, flue linings, sewer pipe, drain tile, red earthenware, stoneware, imitation whiteware, and fire brick. Most of the plants are located close to Louisville. While some of them are supported entirely by raw materials obtained in Jefferson County, others obtain their clays in part from the fire-clay district of eastern Kentucky, and in part from the fire-clay district of Indiana.

Clay-Bearing Formations

These include the following:

1. *Alluvial clays* bordering the Ohio River. None of these are worked, and while their presence has not been investigated, it is probably safe to say that they occur.

2. *Rosewood shale* of Waverly or Lower Mississippian age. Butts (Ref. 2, p. 50) describes this as a bluish gray, unevenly fissile and siliceous shale, whose composition is approximately, silica 68%, alumina 14%, calcium carbonate 5½%, ferric oxide 4%, potash 3%. It may contain some thin limestone lenses and also ferruginous nodules. It occurs capping the ridges east of Coral Ridge, on top of the hills south of Kosmosdale and west of Brooks. It can be used for structural clay products, but is not as good as the New Providence shale, to be next mentioned.

3. *New Providence Shale.* Butts (Ref. 2, p. 137) states that in Jefferson County this outcrops on the sides of knobs in the vicinity of Iroquois and Jacobs Parks, on the lower sides of the Knobs farther southward and in the level spaces between. Its top passes beneath the overlying strata at the north bases of Mitchell and Jefferson Hills, and at the base of the hill at Pleasure Ridge. It also outcrops in the upper part of the valley of Crane Run and of the run just east of Johnstown.

It extends about half way up the side of South Park Hills and Norton Hills. It is also found on the side of the hill east of

Hunters Trace where the shale was formerly dug for brick making. It is quarried for brick on both sides of the Louisville and Nashville Railroad at Coral Ridge.

On Button Mold Knob one mile south of the county line from Norton Hills there are excellent exposures, but here the shale has a number of thin limestone beds.

Six miles southwest of Louisville, along the Illinois Central Railway there is a bank of New Providence shale fully 75 feet high. There was formerly a brick works at this locality, but the bank has been more recently worked by the National Process Company for making potash from the shale. The plant is now idle.

Butts states that the total thickness of the New Providence shale in Jefferson County is 150 to 160 feet. It is a shale of excellent plasticity, and well adapted to the manufacture of clay products.

It may contain concretions of iron carbonate, but these are not always abundant, nor do they appear to be uniformly distributed through the shale. Gypsum may also be present in small amounts.

The two following analyses given by Butts represent: I, the lower part (green shale), and II, the still lower part (blue shale) from Coral Ridge, plant of Coral Ridge Clay Products Company:

	I.	II.
Silica	60.44	60.40
Alumina	19.92	19.73
Ferric oxide	6.48	4.72
Lime	.28	.78
Magnesia	2.01	2.10
Potash	4.85	4.87
Soda	1.00	.96
Phosphorus pentoxide	tr.	tr.
Sulphur trioxide	tr.	tr.
Titanic oxide	.80	.83
Ignition	5.20	5.96
Moisture	.79	.60
	101.77	100.95

Fig. 24. Kiln sheds, P. Bannon Brick Company, Louisville.

4. *Jeffersonville Limestone Clay.* The residual clay from the Jeffersonville limestone underlies a considerable area and is worked for the manufacture of brick and drain tile. It is a plastic, red-burning clay that gives an excellent product.

Clay Working Industry

P. Bannon Pipe Company. This firm has a plant in Louisville, which produces common brick, hollow block, and some fire brick. The raw material used includes shale quarried at the company's pit at Coral Ridge and fire clay obtained from Soldier, Carter County.

The shale pit lies on the west side of the Louisville and Nashville Railroad at Coral Ridge. In the highest part of the working face there is 25 feet of clay derived from the weathering of the shale, and about 25 feet of shale under it. Scattered through the deposit are concretions of carbonate of iron, which are sometimes coated with gypsum as well as containing it in the cracks. The shale is quarried with an excavating machine shown in Fig. 25. It is then taken by rail to the plant at Louisville. There it is ground in dry pans, and tempered in wet pans. The bricks and hollow blocks are all molded in a stiff-mud machine. Drying is done in tunnels heated by live

Fig. 25. Machine for excavating shale, pit of P. Bannon Pipe Company, Coral Ridge.

steam. The plant is equipped with 15 circular down-draft kilns, and firing takes 7 days for hollow blocks and 15 days for the fire brick. The completion is judged by trial pieces.

Coral Ridge Clay Products Company. This company's plant is located 1/4 mile south of Coral Ridge station on the Louisville and Nashville Railway, the product being hollow block, common brick and face brick.

The material employed is the New Providence shale which is quarried in the hill just behind the works, the quarry having a working face of about 50 feet in height. The section showed:

Residual clay	5 ft.
Green shale with scattered iron carbonate concretions, and crusts and films of gypsum	35 ft.
Blue rather hard shale, with no concretions	9 ft.

The green shale and the residual clay are the materials chiefly used, as the lower shale is found rather hard to excavate with the steam shovel. The upper shale shows a tendency to

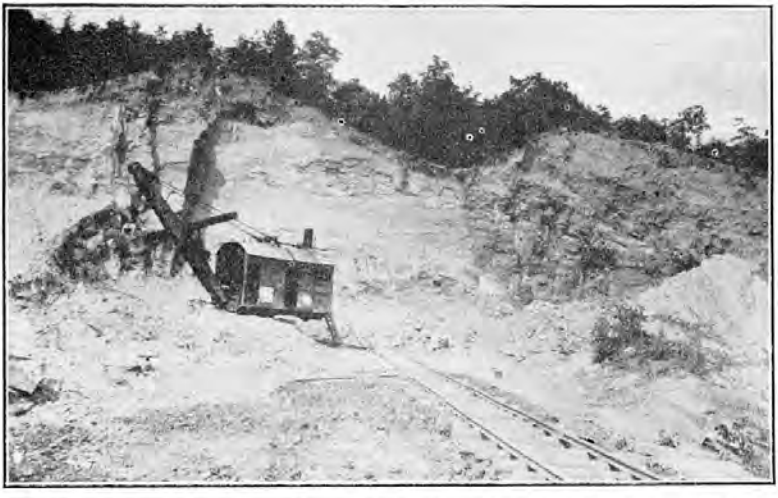


Fig. 26. Bank of New Providence shale, Coral Ridge Clay Products Company, Coral Ridge.

develop drier scum, while the lower shale which is free from gypsum and concretions does not scum, but is less plastic.

The following tests indicate the character of the green shale (Lab. No. 2417) forming the upper three-fourths of the working face:

Plasticity	Very good. Smooth
Lime carbonate	None
Water of plasticity	27.7%
Slaking time, minutes	28
Average transverse strength, lbs. per sq. in.	289
Air shrinkage, linear	4.5%
Color after firing	Red
Steel hard	A little above 950° C.
Soluble salts	Present

Fire tests.

Temp.	Fire Shrinkage	Absorption
	%	%
950° C.	1.5	11.1
1070° C.	8.0	1.8
1150° C.	10.0	0.
1170° C.	Overfired	

This is an excellent shale which is adapted to making brick, hollow blocks, drain tile and common red earthenware.

A sample of the lower shale (Lab. No. 2418), was also tested with the results given below:

Lime carbonate	None
Plasticity	Very good
Water of plasticity	22.2%
Slaking time, minutes	18
Air shrinkage	3.5%
Average transverse strength, lbs. per sq. in.	241
Color after firing	Red
Steel hard	950° C.

Fire tests.

Temp.	Fire Shrinkage	Absorption
	%	%
950° C.	1.	11.1
1050° C.	4.5	2.0
1070° C.	4.5	2.3
1150° C.	6.5	.3
1190° C.	Overfired	

This shale fires to a red color, but not quite as bright as the upper shale. It also stands a little more heat. It should, however, make good brick, hollow blocks and tile.

Fig. 27. Plant of Coral Ridge Clay Products Company, Coral Ridge.

The shale used at the plant is ground in dry pans, screened and tempered in pug-mill. Molding is done in a stiff-mud ma-

chine, and drying in tunnel driers. The plant has 5 circular and 5 rectangular down-draft kilns, all equipped with connections for thermo-electric pyrometer. Water smoking is completed at 350°F. and firing at 1650°F. If flashed brick are to be made, this is done by adding oil to the fires.

Southern Brick and Tile Company. This company has two plants located along the Southern Railway at Whitners station or Buechel postoffice. At one plant common brick are manufactured, and at the other one, drain tile.

The clay used is in both cases residual material from the

Fig. 28. General view, Southern Brick Company, Whitner Station.

Jeffersonville limestone formation, although each plant is supplied from a different pit. This residual clay is said to run 10 feet deep, and that portion of it exposed in the pit of the brick plant shows:

Yellow clay	4 ft.
Red clay	2 ft.

The brick clay (Lab. No. 2419) is somewhat open and siliceous, but has good plasticity. It fires to a good red body at 950°C. with 16.3% absorption. Butts in his report on Jefferson County (Ref. 2, p. 224) gives the following analysis of the clay:

Silica	74.10
Alumina	10.38
Ferric oxide	4.48
Lime	.36
Magnesia	.85
Potash	1.72
Soda	.43
Manganous oxide	.32
Titanic oxide	1.00
Phosphorus pentoxide	tr.
Ignition	4.30
Moisture	1 58
	99.52

The high percentage of silica is consistent with the siliceous character of the clay. The clay also contains scattered chert fragments which are liable to get into the brick.

At the brick works the clay is loaded onto cars in the pit and hauled up an incline to the works where it is tempered in

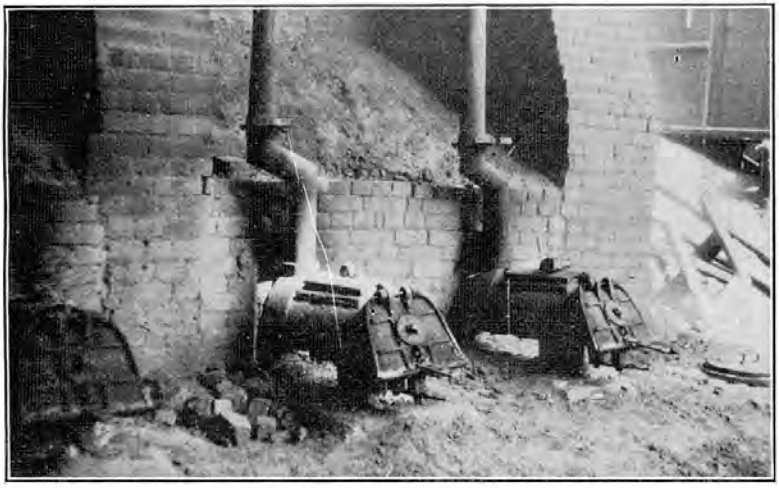


Fig. 29. Burners for using producer gas in brick kilns, Southern Brick Company, Whitner Station.

a pugmill and molded in a soft-mud machine. Drying is done in tunnels, and burning in Dutch kilns. There are five of these, and the fuel used is producer gas. The firing takes 6-7 days.

The drain tile are fired in a circular down-draft kiln.

Progress Brick Company. This works is situated on the Poplar Level road south of Louisville and about 1/4 mile north of Camp Taylor. The product is common and front brick.

Fig. 30. Pit of Progress Brick Company, Louisville.

The clay is residual material derived from the Jeffersonville limestone formation, and the pit which is very shallow lies close to the works. A section in the excavation is as follows:

Soil	1½ ft.
Yellow clay	4 ft.
Red clay	5-6 ft.
Cherty clay	1 ft.
Limestone.	

In digging the clay the chert fragments are rejected whenever possible, and the piles of them in the pit indicate that they are rather abundant especially in the lower part of the clay bed.

After hauling the clay to the works it is stored in the dry shed. Subsequently when ready for use it is crushed, screened, and molded in a dry-press machine. Firing is done in Dutch kilns and takes about 9 days. The clay makes an excellent red brick.

East End Brick Company. This plant has also made brick from the Jeffersonville limestone residual clay, but is no longer in operation.

P. Bannon Pipe Company. The company has a second works at 836 South 13th street and there manufactures sewer pipe, flue linings and chimney tops. The clays used are shale obtained from Coral Ridge, Jefferson County, fire clay from Soldier, Carter County, and No. 2 fire clay from Duff, Indiana. The company also owns clay property near Shorts Station, Daviess County, Kentucky, but is not at present getting any material from there.

The materials are all ground in dry pans, and tempered in wet pans.

Sewerpipe and flue linings are molded in a pipe press, but the chimney tops are molded by hand. Drying is done on floors, and firing in circular down-draft kilns, of which the plant has twelve, all connected with a thermo-electric pyrometer. The firing takes 120 hours, and salt glazing is done at 1950° F. The total shrinkage of the sewer pipe mixture is 14.6%. The clay shows a tendency to scum at times, which is probably due to the Coral Ridge shale.

Louisville Pottery Company. This company's plant is located at Floyd and Broom streets, the product consisting of flower pots, stoneware and some imitation whiteware, the last having a stoneware body covered with an opaque white glaze.

The flower pots are made from the New Providence shale obtained from Bannon's pit at Coral Ridge, while the stoneware is manufactured from a No. 2 fire clay mined at Huntingburg, Indiana. Sagger clay is obtained from the Purchase region.

The flower pots are molded in a machine for this purpose.

The stoneware clay is moistened, crushed and stored for some time before using. It is then disintegrated in a dry pan, mixed in a blunger, and forced from this through a 40-mesh screen into the filter press where the excess of water is squeezed out. The material is then ready for molding.

The pottery is equipped with 5 circular down-draft kilns, and firing of stoneware requires 72 hours. The earthenware flower pots are fired at 1800° F. and the stoneware at 2300° F., the firing being checked with a pyrometer. Albany and Michigan slip clays are used for glazing the stoneware.

The market for the product is in the central states.

Louisville Firebrick Works. The Louisville Firebrick Works has a plant located at Highland Park, south of Louisville, on the Louisville and Nashville Railroad. In addition it also has a works at Grahn, Carter County.

At the former plant the product consists of standard fire brick of different grades, locomotive blocks, rotary kiln brick, stove backs, etc.

The fire clays used are obtained in part from the company's mines at Grahn, and in part from Huntington, Ind. The Grahn

Fig. 31. Molding special shapes, Louisville Fire Brick Works, Highland Park.

clays are in part flint clays, while the Indiana material is a No. 2 fire clay.

The clays are crushed in dry pans and tempered in wet pans. Standard shapes are made in a modified type of dry-press machine. Large pieces and special shapes are molded by hand. The drying is all done on floors which are heated by steam pipes laid beneath them, and by hot air forced into the drying rooms through large pipes.

Firing is done in circular down-draft kilns of which there are 16, and requires 6 days to reach high fire. No pyrometer is used, but cone 9 is said to be turned over.

Fig. 32. Kilns at Louisville Fire Brick Works, Highland Park.

The daily capacity of the plant figured in terms of 9-inch brick is 50,000.

The XXX and the Bung brands represent the best grade of brick produced by the works. The No. 1 and Louisville brands are the next best, the former being a hand-made repressed brick, and the latter a machine-made one.

The following analyses and other tests have been supplied by the company.

	XXX Hand Made Brick	Louisville Machine Made Brick	No. 1 Hand Made Brick
Silica	56.60	59.20	59.46
Alumina	40.22	37.84	35.98
Ferric oxide	1.64	1.90	2.39
Lime	.20	.24	.43
Magnesia	tr	tr.	.27
Soda	.90	.96	.77
Ignition loss	.40	.04	.....
Titanic oxide	.....	.....	1.05
	99.96	100.18	100.35
Cone of fusion	33+	32	31

The compression in the standard load test at 1345°C. was 8.51%. The permanent contraction in the reheating test at 1400°C. was .33%. The penetration in standard slag test was .93-.97 square inches. The average total of cold crushing strength was 25,250 pounds. In the spalling test the brick lost 35% on the fifth dip when tested as received. When they were reheated before spalling they lost about 50% on the sixth dip.

In connection with the latter test it may be explained that the brick is weighed and then heated to 1300-1350° for one hour. It is then placed on end in a tank of cold running water for 3 minutes. This is followed by 5 minutes air drying, after which it is replaced in the furnace. The procedure is repeated until pieces of the brick begin to spall off. In the reheating test the brick is first heated to 1350°C. after which it is cooled. It is then put through the test as outlined above.

Jessamine County

This county is entirely underlain by residual clay derived from Ordovician limestones. This type of clay is being used at Nicholasville by Schneider and Sons for brick manufacture. The yard was formerly located on the south side of town, but the clay gave out and it was moved to the north side of the village along the road to Lexington. The clay is residual, derived probably from the Jessamine limestone, and the product is common brick. The plant is equipped with a soft-mud machine, pallet racks for drying, and Dutch kilns.

Kenton County

In this county two types of clay occur, viz., flood-plain clays, and residual clays. There is also a possibility of finding deposits of Eden shale similar to those which are worked across the Ohio River at Cincinnati, for making common brick.

There are also several clay-working plants in operation making brick and tile, as well as clay pits to supply foundries.

Floor and Wall Tile. The Cambridge Tile Manufacturing Company has two plants in Covington. These are engaged in the production of Ceramics or small tile of different colors for floors, also bright and matte glazed wall tile, with either flat or embossed surface, and of plain white or different colors. In ad-

dition the firm makes a specialty of various styles of figures and letters for signs and bulletin boards. An excellent example of the latter is a large train service bulletin board in the Union Station at Cincinnati.

The clays which are used come mostly from other states, with the exception of sagger clays which are obtained from the Purchase region of Western Kentucky.

The following are examples of work done by the Cambridge Tile Manufacturing Company:

Hotel Gibson and Metropole Hotel, Woodward High School, Cincinnati, O. Ceramic Mosaics for the floors, white glazed wall tile and trim for bathrooms, etc.

Rock Island Railroad Depot, Rock Island, Ill. Ceramic Mosaics for the floors.

The Arcade, Dayton, O. Ceramic Mosaics for the floors.

Central Savings Bank and Trust Company, Covington, Ky. Floors of Ceramic mosaics and wainscoting of white wall tile and trim.

Brick Works. The Busse Brick Company has a works located along the Louisville and Nashville Railroad at the southern edge of Covington. The product is common brick.

The clay, which is a flood-plain deposit, is from 10 to 15 feet thick. It contains scattered pebbles of quartz and limestone, and fires to a red color.

The plant is equipped with a pug-mill for tempering, and soft-mud machine for molding. Tunnel dryers are used, and the brick are run through these in 24 hours, although some trouble is experienced with cracking.

The firing which is done in rectangular up-draft kilns takes from 12-14 days, and the bricks settle 8-10 inches in 38 courses.

Broering and Meier have a common brick plant located on Delmar street at the Licking River. The clay is a flood-plain deposit in which two openings have been made at different levels. That obtained from the lower pit is darker and more tender, although in character it is somewhat open and soft. That from the upper pit, which lies about 15 feet higher than the preceding, is yellow, less tender and stronger. Both clays contain some limestone pebbles and also a few of quartz.

The clay is hauled up an incline from the pits, and discharged into a feeder which delivers it to the rolls. It is then passed on to a pug-mill and molded in a soft-mud machine. The bricks are dried on pallets and left there from 7 to 10 days, while the firing which consumes from 9 to 12 days is carried out in Dutch kilns. The bricks settle 6 to 8 inches in 38 courses.

The clay burns to a good red brick. It is disposed of chiefly on the markets of Covington and Cincinnati.

In former years a brick yard was also in operation at the head of Russell street. Gardner (Ref. 13, p. 207) describes the clay as being of yellow color, mottled with light bluish gray. He also gives the following analysis of the material:

Silica	68 36
Alumina and ferric oxide	22.25
Lime	1.00
Magnesia	1.18
Potash	2.13
Soda	.90
Sulphur trioxide	.25
Ignition	3.65
	99.72

Clay Pits. S. J. Moore of 905 Lewis street, Covington, has opened a pit from which he obtains molding sand and "fire clay." The latter material is used by foundries and malleable iron works.

It is found near the top of the hills in the Park on Light Hills, and is possibly a residual clay from the Eden shales. The section in the pit shows:

Sandy clay	4-6 ft.
"Fire clay"	8 ft.

The so-called fire clay is not really such, for it fires to a red steel-hard body even at 950°C. However, this does not interfere with its being of service in foundries and iron works, where clays are used for patching and plugging in places where they are not exposed to a very high temperature.

E. M. Light, of Light Hills, near Covington, claims to have a deposit of terra cotta clay, but so far as known none of it has been shipped.

Madison County

Clay Formations. The western two-thirds of Madison County is underlain by Ordovician limestones, which may supply residual clays suitable for brick manufacture. In this same part of the county it may be possible to find local flood-plain deposits along some of the streams, which could be used to support a small brick plant.

In the eastern third of the county the clays are of much greater value.

Here we find scattered deposits of the Irvine formation which is of Tertiary age (Chap. 1), and these clays are adapted to the manufacture of stoneware. They are very plastic dense-burning clays, which at present are being utilized at Waco and Bybee to make stoneware, blue art pottery, brick and tile. They have also been used in the past for roofing tile.

Foerste (Ref. 11, p. 160) says: "Probably no class of clays in the central part of Kentucky has aroused a wider interest for a longer time than those from the Irvine formation in various parts of Madison County. From no area of similar size have we as many analyses. This is due to the fact that at an early date a fairly extensive production of common stoneware was founded upon the use of this clay, and that this stoneware industry is still in existence."

These deposits are never deep and so far as known never of great extent, but they appear to be scattered over a rather extensive territory, and it would seem that in the aggregate they might furnish considerable clay.

In this same part of the country there are also found deposits of Niagara shale and New Providence shale, although they are not as favorably located for working as at other points.

Pottery Clays. There are two potteries in operation in Madison County, one at Waco and the other at Bybee.

Waco Pottery Company. This is operated by Messrs. Grimstead and Stone. The product consists of stoneware crocks, jugs and bowls. In addition they make a blue glazed art ware, for candlesticks, vases, flower bowls, etc. A small quantity of brick and drain tile is also produced, the pottery branch being looked after by Mr. Stone and the brick and tile by Mr. Grimstead.

Fig. 33. Waco Pottery, Waco.

The pottery is located on the pike about 1/2 mile east of Waco, and the clay pit is about 1/4 mile south of the pottery.

The pit is a shallow excavation in the woods, the section showing a yellowish sand above which grades down into a tough smooth brownish clay. The tough clay is said to run 3 to 4 feet thick, and below it there is gravel. The gravel rests on Ohio black shale.

The following tests give the physical properties of this material (Lab. No. 2440):

Working qualities	Very good
Plasticity	Very good
Water of plasticity	26 3
Modulus of rupture, lbs. per sq. in.	678
Air shrinkage (linear)	5%
Color after firing	Reddish buff
Steel hard	950° C.

	Fire Shrinkage	Absorption
	%	%
950° C.	3.5	4.6
1050° C.	5.0	4.8
1090° C.	5.5	3.5
1130° C.	6.0	.4
1190° C.	7.5	.1
1250° C.	7.5	.1

This is an excellent dense-burning clay of stoneware type. It has a high modulus of rupture, in fact the highest of any of the series tested. It could probably be used also for roofing tile and other wares in which a vitrified body is required.

Half way between the clay pit and the pottery the black Ohio shale outcrops, but little below the level of the clay pit. Under the Ohio shale is a soft gray stratified clay shale about 8 feet thick, with sandstone at the bottom. It is not known whether this is the base of the shale, or whether it extends below the sandstone, in which case the latter represents a sandy layer in the shale that would have to be removed. This same shale is struck in greater thickness in well drillings to the eastward. In its appearance and properties the shale closely resembles the Niagara. The properties of this shale (Lab. No. 2439) are given below:

Lime carbonate	A little
Working qualities	Very smooth
Plasticity	Very good
Slaking time, minutes	22
Air shrinkage (linear)	6%
Color after firing	Red
Steel hard	950° C.

	Fire Shrinkage	Absorption
	%	%
950° C.	5.0	3.4
1050° C.	8.0	2.4
1150° C.	11.0	.4
1190° C.	Overfired	

This clay fires to a hard body even at 950°C. It might be mixed with the stoneware clay dug nearby and could also be used in brick and tile. Possibly also for common red earthenware. The slope of the land is such that enough could be dug to supply the pottery without having to remove much overburden.

The stoneware at the Waco pottery is made from a mixture of the Irvine clay with one-third sand. The mixture is tempered in a pug-mill and thrown on a kick wheel. It is fired to cone 5 in a small circular down-draft kiln, the firing requiring 60 hours. The stoneware is glazed with a mixture of Albany

and Michigan slip clays, which is darkened by adding manganese oxide to it. The blue ware which is quite attractive is produced by covering the stoneware with a blue glaze.

For brick and tile the Irvine clay alone is used. It is tempered in a soakpit and molded in a stiff-mud machine operated by horse power. The ware is fired at cone 2.

The product is sold in the surrounding country.

A small sample from a new deposit of pottery clay was sent in to the Survey by Mr. Stone, of Waco.

This sample was too small to do anything with except burn a couple of samples. From these could be determined the fact that the material is a plastic clay which fires to a good buff color. It has 10.8% absorption at 1190°C., and 5.% absorption at 1230°C. The former temperature corresponds to cone 3 and the latter to cone 5. Mention is made of this as the potters at Bybee use cones in their kilns. The material could probably be used in their stoneware mixture, but it is not as dense burning as the clay which they were using for making their stoneware in the summer of 1921.

Bybee Pottery Company. This plant, which is located at Bybee, produces only hand made "Bybee" blue art pottery, which is sold locally and throughout the United States and Canada. It was the first of the two to make the blue glazed stoneware. The stoneware is said to be fired at cone 6.

The clay for this pottery is obtained from a pit owned in fee by the Bybee Pottery Company on what was known formerly as the Mrs. C. S. Rupard farm, which lies on the north side of the road between Waco and Bybee. It is a gray plastic clay, belonging to the Irvine formation, and having a thickness of 3 feet with 3½ feet of sandy clay overburden. It is underlain by quicksand and care has to be taken not to uncover it in digging the clay as it is waterbearing. The clay is hauled 1 1/2 miles to the Bybee Pottery at Bybee. In its physical properties it is similar to the Waco Pottery's clay, but apparently takes a little more heat in firing

A sample of the Bybee Pottery Co., (Rupard) pottery clay, from near Waco, collected by T. B. McCoun, Lexington, Ken-

Fig. 34. The Old Pottery at Bybee.

tucky, was sent in to the Geological Survey for testing. The results were as follows:

Plasticity, good.

Water of plasticity 30%.

Linear air shrinkage 7%.

Modulus of rupture of the clay alone, 179 pounds per square inch, which is fair.

Fires to a cream white color at 1150°C.

Steel hard at 1170°; and nearly so at 1150°C.

Absorption at 1150° is 16%, at 1190° it is 11.8%, and at 1230°C. it is 7.%.

It is not a very dense burning clay at the temperatures given. The material could be used probably in the manufacture of chemical stoneware, terra cotta, electric insulators, face brick and saggers.

Foerste (Ref. 11, p. 162) notes several other localities at which the Irvine clay has been found. All of these known deposits have now been worked out and abandoned.

One of these is on the G. S. McKinney property, ¼ mile south and ¼ mile east from Waco. Another one on the Adams farm near Waco, was used at one time at Searcy to make roofing tiles.

Fig. 35. Making pottery by hand at Bybee.

At Moberly there is another deposit which is doubtfully referred to the Irvine formation. Foerste gives the following analysis of this:

The two following analyses were supplied by Dr. A. M. Peter, chief chemist.

Silica	74.36
Alumina	7.79
Ferric oxide	6.78
Lime	.14
Magnesia	.53
Potash	1.59
Soda	.49
Titanic oxide	1.25
Ignition	4.20
Moisture	1.98
	99.11

This clay was being used for brick and tile by the Moberly Brick Company in 1904. The plant is not running now.

The two following analyses were supplied by Dr. A. M. Peter, Chief Chemist.

Laboratory No. G-4074.—Clay, labeled "From Messrs. Grimstead & Stone, Waco Pottery Co., Waco, Madison Co., Ky." Received April 1, 1922, from Dr. W. R. Jillson, State Geologist, Frankfort. The sample was about a pound lump of light smoke-gray or buff colored clay.

ANALYSIS.

	Per Cent
Moisture	3.72
Volatile matter	5.76
Silica	59.98
Ferric oxide	7.98
Alumina	16.46
Titanic oxide	0.80
Calcium oxide	1.12
Magnesium oxide	1.04
Sodium oxide	0.62
Potassium oxide	3.43
Total	100.91

Laboratory No. G-3885.—Clay received January 7, 1920, through J. E. Barton, Commissioner of Geology and Forestry, from J. W. Cook, Richmond, Madison County, Ky. The sample was about a pound lump of yellow or buff colored clay.

ANALYSIS.

	Per Cent
Moisture	2.39
Ignition (combined water, etc.)	5.81
Silica	69.42
Alumina	13.20
Ferric oxide	3.44
Titanium dioxide	1.08
Calcium oxide	1.29
Magnesium oxide	0.90
Sodium oxide	.32
Potassium oxide	2.50
Total	100.35

Another analysis of an Irvine clay from Waco, is also given by Foerste. It runs:

Silica	62.58
Alumina	21.98
Ferric oxide	4.78
Lime	tr.
Magnesia	1.276
Potash	2.607
Soda	0.500
Manganous oxide	tr.
Sulphur trioxide	.234
Ignition	6.14
	100.097

Shales. New Providence (Linietta) shale is said to outcrop 1.5 miles northeast of Berea on the Kingston Pike. It is supposed to represent the lower 40 feet of the Waverly. No physical properties are given. Foerste quotes the following analysis:

Silica	65.58
Alumina	16.00
Ferric oxide	5.51
Lime	.03
Magnesia	1.25
Potash	3.89
Soda	.82
Titanic oxide	1.13
Ignition	4.29
Moisture	1.75
	100.25

About 3 miles southeast of Berea on Bear Mountain is a deposit of plastic shale of probable Pennington age. According to Foerste it fires to a light red color.

Marion County

The northern half of the county is underlain by residual clays from Ordovician limestones. In the southern half the New Providence shale occurs and is crossed by the Louisville and Nashville Railroad south of Lebanon.

The Goodwin Brick and Tile Company has a plant at Lebanon, located on the south edge of town. Both common brick and drain tile are produced.

These are made from a residual clay derived from limestone, so that the depth of the clay is somewhat irregular and varies from 7 to 15 feet. It also varies from gray to red color. Some portions of the deposit contain fragments of chert, these being especially abundant in a 5-foot zone at the south end of the bank. The top clay gives much trouble because of its tendency to laminate and crack, and for large tile some of the bottom clay has to be added even though it has a higher shrinkage. If cracks develop in the brick or tile, it takes place within five minutes after they are molded. If not, no further trouble is experienced.

Both the brick and tile are molded in a stiff-mud machine, and dried in the open air, the tile under sheds and the brick protected by boards. The ware is fired in a 30-foot circular down-draft kiln, the firing requiring 5 days. Both trial pieces and cones are employed, the temperature being sufficient to bend cone 010. The bricks are of a good red color and excellent ring.

Mason County

The only clays of importance are the flood-plain clays along the Ohio River. Residual clays may be found over the Ordovician limestones but are not used. A small patch of Silurian shale may be found towards the eastern margin of the county.

Maysville. Two brick plants are located a short distance east of Maysville, along the Ohio River. Both are using flood-plain clays, and both are located on the Chesapeake and Ohio Railway. The Louisville and Nashville also reaches Maysville, so that the product can be shipped by two railroads or by water.

Spahr Brick Company. This firm has a large and well equipped plant about 2 miles east of Maysville, the product including common, pressed and rough texture brick.

Fig. 36. General View, Spahr Brick Company, Maysville.

The section in the clay pit shows:

Soil and top clay	1 ft.	
Light colored loamy clay, average	6-7 ft.	Maximum 15 ft
Sand, not used	.....	

There are a few pebbles in the clay and considerable very fine mica.

The clay is dug with a steam shovel, loaded onto small dump cars and hauled up to the sheds. Here it is passed through rolls, and then a pugmill. Molding is done in a stiff-mud machine, 30,000-45,000 brick being made in a day. Tunnel dryers are used, the brick taking 4-5 days to dry. There are 7 rectangular kilns, 5 of these being down-draft. Steam under pressure is fed through ¼-inch jets, with ⅛-inch holes, into the bottom of each grate, and this is claimed to give a forced draft which greatly reduces the time of firing. The burning takes 5 days.

The bricks show a total shrinkage of about ⅝ inch, but the top clay in the bank shows more shrinkage than the bottom.

No pyrometer is used and the completion of the burning is judged by the amount of settle in the kiln.

The common bricks are a good red color, and the rough texture bricks are fired to different shades, usually a deep or dark red.

Maysville Brick Company. This firm operates a large brick plant located about ⅛ mile west of the preceding, and lying be-

Fig. 37. Kiln sheds, Maysville Brick Company, Maysville.

tween the Chesapeake and Ohio Railway and the Ohio River. Only common brick are made.

The section in the clay pit is:

Soil	1 ft.
Clay	8 ft.
Sand	1 ft.

There are some pebbles in the clay but these are usually disposed of by the crusher. The clay is dug with a steam shovel and hauled to the works in small dump cars. There it is passed successively through a disintegrator, a crusher, and then a soft-mud machine having an automatic device for sanding and striking off the molds.

The drying, which is done on pallet racks, requires about 10 days as the clay is tender, and the firing carried out in Dutch kilns also consumes about 10 days. The settle amounts to 10-12 inches in 40 courses. The plant has a daily capacity of about 40,000 brick. The bricks are hard and of a good red color.

Montgomery County

There is a possibility of obtaining both the Niagara and New Providence shales in this county. Foerste (Ref. 11, p. 39) notes that on the Frenchburg-Jeffersonville road, about 2½ miles east of Jeffersonville, a road branches off to the south. Just west of the forks the main road crosses a small run. At this point the Cuyahoga (New Providence) shale is exposed with a thickness of 17 feet. It contains scattered concretions and the beds below this are mostly sandstone. Other exposures are said to occur in the county but the shale does not show up very thick.

Nelson County

Residual clays from limestones may be found in the northeastern half of the county, while in the southwestern half the Ohio shale is present, and small areas at least of the New Providence.

One clay working plant is in operation, viz., the Nelson Brick and Tile Company at New Haven. This was operated in 1920 under the name of Boone and Bolden. The product consists of drain tile but common brick are also to be made.

Fig. 38. Nelson Brick and Tile Company, New Haven.

The material used appears to be a residual clay derived from the Ohio shale, for the latter outcrops all around the hill at the same level as the clay. Black shale is also exposed in the creek bed, and partly weathered shale has been found in the bottom of the pit.

The top clay alone is used for small tile, but for large ones some of the partly-weathered shale is mixed with the clay. The clay has to be hauled a half mile to the yard.

Powell County

Powell County lies in the Knobs region and contains sedimentary rocks ranging from Silurian to Carboniferous, but none of them are used. In addition to these formations there are also alluvial clays along the valley of the Red River, and these are the only ones worked at present in the county.

Several deposits of shale or clay have been noted in earlier reports of the Kentucky Geological Survey and reference to them is made below.

Alluvial Clays

Stanton. Atkinson and Baker are operating a plant located about 1¼ miles east of Stanton on the Lexington and Eastern division of the Louisville and Nashville Railway. The plant

was originally owned and operated by H. Derickson who made drain tile, but the present owners are producing only common brick.

The clay pits are located in the Red River Valley, and are flooded during high water. The section, determined in part from boring is:

Yellow flood-plain clay	22 ft.
Blue "soapstone"	5 ft.
Flinty limestone	3 ft.
Ohio shale	

The clay is smooth and plastic, and is usually dug to a depth of 15 feet, only the 2 or 3 inches of top soil being stripped off. After the clay is dug it is hauled up a small incline and dumped into a stiff-mud machine without any previous tempering, or the addition of water. The bricks are dried under sheds and burned in Dutch kilns. The product is pale red in color, and the only kiln full which the present owners had burned was being used in the construction of the new Presbyterian church at Stanton.

Clay City. Another deposit of alluvial clay is found along the Red River, on the J. M. Kennon place, situated on the Clay City and Hardwick road, 1 mile from Clay City. (Ref. 10, p. 879). It was used for brick making at one time. The deposit is 6 feet thick with 2 feet of sandy overburden. The following properties are given for the clay:

Plasticity	Good
Air shrinkage	6%
Tensile strength, lbs. per sq. in.	101
Fire shrinkage	12%
Color after firing	Red
Cone of incipient fusion	1
Cone of vitrification	6

Filson Station. Foerste (Ref. 11, p. 75) notes a dark plastic clay in the Lexington and Eastern Railway cut, 1 mile east of Filson, on the Jesse Faulkner farm. It is described as a 7-foot bed of alluvial clay which rests on Waverly shale. The physical qualities are described as follows:

Plasticity	Excellent
Air shrinkage	7%
Tensile strength, lbs. per sq. in.	171
Fire shrinkage	8%
Color after firing	Grayish brown
Cone of incipient fusion	4
Cone of vitrification	7

Carboniferous Clays

Rosslyn. Easton (Ref. 10, p. 880) has noted the occurrence of clay deposits on the John Wasson farm on the Rosslyn and Cat Creek road, 4 miles south of Rosslyn.

The clays, which Easton claims are fire clays, are said to form a 3-foot bed at the base of the Pottsville conglomerate. Below the clay is a bluish plastic clay. The fire clay is very lean, and fires to a soft body at cone 11.

New Providence Shale

Stanton. The Cuyahoga shale is exposed as a deposit 17 feet thick, one mile north of the iron bridge on the Morris Creek highway.

Clay City. A deposit of bluish shale (Ref. 10, p. 71) 14 feet thick, lying on top of Ohio black shale is found on the E. Rose place 1 mile east of Clay City. The properties are given as follows:

Plasticity	Very good
Air shrinkage	3%
Tensile strength, lbs. per sq. in.	73
Fire shrinkage	3%
Color after firing	Red brown
Vitrification, at cone	7

There is some doubt as to the age of this material. If it belongs to the New Providence shale formation, it shows a higher vitrification point than this shale usually does. The latter is nearer to that of the clays of the Irvine formation found in Madison County.

Devonian

Stanton. A greenish yellow clay, said by Easton (Ref. 10, p. 881) to be of Hamilton age is found in the Lexington and

Eastern Railway cut 50 yards west of Stanton. The thickness of the deposit is not given. Easton gives the following properties for it:

Plasticity	Fair
Air shrinkage	4%
Tensile strength, lbs. per sq. in.	102
Cone of vitrification	7
Color after firing	Red brown

Niagara Shale

Virden. Easton (Ref. 10, p. 877) notes the occurrence of Niagara (Crab Orchard) shale in the first cut east of Virden on the Louisville and Nashville Railroad. The deposit is only 4 feet thick and has 25-29 feet overburden. Unless found at some other nearby point in greater thickness and with less overburden it is not to be regarded as a workable proposition. The shale fires to a dark brown color.

CHAPTER VI.

THE EASTERN COAL FIELD

In this chapter there are included not only the counties in which the Pennsylvanian rocks are the predominating surface formations, but also a few counties such as Lewis and Rowan, which it seems more desirable to include in this chapter because they lie east of the main belt of the Knob country.

The clay and shale-bearing formations which may occur in this area are the following:

Silurian Shales. The Estill and Lulbegrud shales if present in workable quantity are to be sought for only in the western part of Lewis County.

Devonian Shales. The Ohio black shale is to be found in northwestern and western Lewis County, and is also found at a number of points along the western border of the eastern coalfield, but in its fresh condition is of no value for the manufacture of clay products. In isolated outcrops it is indistinguishable from the Sunbury shale, unless there are other key horizons associated with it. It is present in considerable quantity in the hills around Vanceburg.

Mississippian Shales. The Mississippian formations underlie a large part of Lewis County, Rowan County, and narrow belts along the drainage lines of Tygarts Creek and its tributaries in Greenup and Carter counties. A narrow belt also crosses the southeast portion of the area included in this chapter, extending from southwestern Bell County up to Elkhorn City in Pike County. Furthermore, there is no straight boundary line between the Pennsylvanian and Mississippian formations along the western border of the eastern coalfield, the two being more or less interfingered as shown on the geologic map of the state issued by the Kentucky Geological Survey.

The shale formations that may be present are the Bedford, Sunbury and New Providence of the Waverly series, and undifferentiated shales of the Chester series.

The Bedford shale can be used for brick but is not present in large deposits, nor as desirable as the New Providence.

The Sunbury shale is of no value, being similar to the Ohio shale when fresh. If completely weathered it forms a ferruginous clay.

The New Providence shale is an excellent material for bricks, tile, hollow blocks, common red eartherware and sometimes paving brick. It is worked only at Firebrick in Lewis County, but can be found at other points to the southwestward.

The Waverly shales and sandstones form a large part of the surface of Rowan County to the north and west of Morehead, and some of these may be of value for paving brick and sewer pipe according to Crider. (Ref. 8, p. 643).

Chester shales are probably sparingly present in the area here discussed.

Pennsylvanian. Pennsylvanian formations include the Pottsville, Allegheny and Conemaugh series, and are of considerable importance to the clay-working industry.

Pottsville. At the base of the Pottsville* there is found an extensive, but not continuous, deposit of fire clay which has assumed great importance, and which is sometimes referred to as the Olive Hill fire clay because of the locality in Carter County where it was first developed.

Characters of the Olive Hill Clay. This fire clay deposit is made up of three different grades of clay known as: 1, flint; 2, semi-hard, semi-flint or soft-hard, and 3, No. 2 plastic.

The flint clay is very fine grained, has a conchoidal fracture, and in color is often buff or gray, but sometimes dark gray, black or even red. It occasionally grades into a sandy phase, which contains minute grains of quartz. At a few localities an oolitic variety of flint clay is found, which contains small oolites embedded in a matrix of normal flint clay. This variety was described by Graves-Walker as occurring in the Burnt House mine at Olive Hill, (Ref. 19), and he proposed the name of *Aluminite* for it. A peculiarity was its high percentage of alumina, which is not surprising considering, as shown by Galpin (Ref. 16) that the oolites are composed of the mineral Gibbsite or hydrargyllite, ($Al_2O_3.3H_2O$). This oolitic type is no longer found at Olive Hill, but Crider has noted several other occurrences of it. (Ref. 8, p. 653).

*This refers to the lowest part of the formation present in this area.

PHOTO BY W. R. JILLSON.

Fig. 39. Face or flint clay in mine at Grahn.

While the pure flint clay is of high refractoriness, the deposits of it may occasionally show impurities such as pyrite, concretions, and films of gypsum, the latter occurring in the irregular cracks that traverse the flint clay in all directions, but not in sufficient quantities to reduce its refractoriness. Quartz grains are present where the flint clay grades into sandstone.*

A somewhat detailed study of the microstructure of flint clays, made by Galpin, (Ref. 16), shows that the flint clay contains kaolinite, hydromica, pyrite, quartz, rutile, zircon, and tourmaline. All of these except the first two are commonly present in only small amounts. In the *aluminite* clay, gibbsite was identified in considerable quantity.

The semi-hard clay differs from the flint in being slightly softer, in having noticeable plasticity, and in showing the presence of numerous slickensided surfaces which commonly traverse the clay in all directions. It is usually quite sharply separated from the flint clay. Like the flint clay it may contain pyrite concretions and gypsum films at times, and in some mines it was coated on the slip surfaces with minute white specks of about 1/32 inches diameter.

Galpin from his microscopic studies found that hydromicas were much more abundant than kaolinite.

No. 2 plastic clay differs from the other two in having decided plasticity. It is softer than the semi-hard, but shows an abundance of slickensides. It is the least refractory of the three fire clays found together.

Relation of the three Fire Clays. A careful comparison of the sections shown in different mines brings out the fact that there is no definite order of deposition exhibited by the flint, semi-hard and No. 2 plastic clays. While it is true that a definite relationship may hold throughout one mine, it does not hold in all parts of the area in which these clays occur. In some mines practically nothing but flint may occur, in others only semi-hard, but none was seen where No. 2 plastic alone is found.

It is not common to find any one of the three varieties forming the entire deposit in any one mine.

Extent of Fire Clay Deposits. The three associated fire clays just described are found throughout a wide area of terri-

*C. E. Bales has recently found some veinlets of galena in the flint clay.

tory extending from the Ohio River on the northeast, to Elliott County on the southwest. Along the line of the Chesapeake and Ohio Railway they are found from Aden on the east to Morehead on the west. This is not to be taken as signifying that the fire clay occurs throughout this area, for there are localities where it is lacking, indeed it probably represents a series of separate deposits which are somewhat closely connected. This seems to be shown first by the fact that in some localities drill holes have not encountered fire clay, and secondly that in some deposits the fire clay grades horizontally into sandrock.

Roughly speaking the area within which the fire clay deposits have been found is about 660 square miles.

Within this area the development has been chiefly in a zone bordering the Chesapeake and Ohio Railway, no company at present hauling its clay from points more than 5 miles distant, and then over private narrow gauge railroads. Much drilling has, however, been done in practically all parts of the area, and reserve supplies blocked out so that the several firebrick companies either own extensive undeveloped clay tracts or control the mineral rights on them. As time goes on and the supplies near the railroads become exhausted those farther away will be developed.

There is no doubt a considerable reserve tonnage in the district as a whole, but it would be impossible to state just how many years it is going to last.

The thickness of the fire clay as determined from a study of the beds and drill records ranges from zero to 29 feet. The last figure is said to represent a bed of solid flint clay. The distribution of working mines, and prospects so far as known are shown on the maps, Figs. 42 and 56.

Relation of Fire Clay to Underlying Formations. The most prominent formation below the fire clay is the Maxville limestone, and at most localities where the fire clay occurs the limestone is found below it in the section. It is sometimes absent, due probably to erosion that occurred before the period of fire clay deposition, as at Iron Hill, Carter County, where Crider states that the flint clay rests directly on the Waverly sandstones and shales. In few cases does the fire clay rest directly on the limestone, but on the contrary it is usually separated from it

by a red mottled plastic clay known as "pinkeye," by sandstone, or by shale. Crider (Ref. 8) in his admirable detailed report on the Olive Hill district states that the pinkeye is calcareous, and furthermore that it is a residual deposit derived from the Maxville limestone. We have not found any pinkeye that was calcareous in its nature, nor can we agree with him that it is a limestone residual, for the reason that in many cases it does not rest directly on the limestone, there being sandstone sometimes between them. It may be noted here that the pinkeye is usually a mottled clay, of low refractoriness. Occasionally, however, it is sufficiently pure to be used in fire brick.

Immediately on top of the limestone there is sometimes a cherty mass that appears to have been altered by weathering, and which may be from 1 to 3 feet thick, as in the mine of the Ironton Firebrick Company at Enterprise, Carter County.

The interval between the bottom of the fire clay, and the top of the limestone is exceedingly variable. Thus in a number of drill records examined it was found for example that the distance from fire clay to limestone ranged from 1 foot 8 inches to 25 feet. The highest figure represents nothing but sandstone, the pinkeye being absent. One section showed 22 feet of shale between the limestone and the fire clay. In another section there was sandstone between the pinkeye and the fire clay. In still other cases the floor of the fire clay may be pinkeye at one place and sandstone at another, even within the same mine.

There is no doubt that the fire clay is separated from the Maxville limestone by an unconformity, and this break may be above the shale and sandstone sometimes found overlying the lime rock. That this unconformity represents considerable erosion in places, and uneven erosion is shown not only by the variable thickness of the limestone, which ranges from about 0 feet to 100 feet in the district, so that in some drill holes the lime is entirely wanting and the fire clay rests on Chester Sandstones.

It is probable that some of the soft sandstone associated with and grading into the fire clay, and also the pinkeye lie above the unconformity.

Relation of Fire Clay to Overlying Formations. The material immediately overlying the fire clay may be coal, shale, sandstone, coarse conglomerate, or Pottsville pebbly sandstone.

The coal found associated with the clay, is usually above the fire clay, and often rests directly on it. Occasionally it occurs within the fire clay deposit. It is rarely over 6 inches in thickness and may even be absent.

The shale occasionally found above the clay appears to be conformable with it, and is sometimes quite carbonaceous. It may also contain concretions of siderite and pyrite. At Hayward there is between the shale and the fire clay a hard sandstone known as "whim rock," which is fine grained and contains small angular particles of flint clay. It is not a portion of the Pottsville conglomerate.

At some localities notably at Grahn, the Pottsville conglomerate rests directly on the fire clay in places, but in one mine there are found flat lenses of a coarse conglomerate, consisting of pebbles up to an inch in diameter, in a matrix of quartz sand with mica scales. The pebbles consist in part of shale and of siderite concretions, such as are found in the shale overlying the clay where this material has not been eroded.

There is here then an unconformity between the Pottsville and the fire clay with its overlying shale, and a similar unconformity has been noted in other mines. The thickness of the Pottsville between the surface and top of fire clay is variable, and the range shown in the number of drill records examined ranged from 50 to 130 feet.

In the sandstones overlying the fire clay, there are found one or several beds of a mottled clay known as "Huckleberry clay," which is non-refractory. The thickness of the Huckleberry as seen in different drill holes varied from 2 to 15 feet. The interval between this clay and the fire clay in different drill holes ranged from 2 to 35 feet. In two holes where no fire clay was present there was 20 feet of sandstone between the huckleberry and limestone in one case, and 39 feet of shales and sandstone in another. In short the Huckleberry does not appear to occupy any definite position in the section above the clay.

Age of the Fire Clay. There has been considerable discussion regarding the geologic age of the flint and associated fire

clays in the Olive Hill and surrounding districts, and the majority of writers have usually referred to them as being of Pottsville and not Mississippian age.

As time was not available to make a detailed study of the stratigraphic relations of these flint clays, it might seem presumptuous to express an opinion on the subject of the age, but there is no objection to discussing the evidence that has thus far been published, and in pointing out certain structures that some appear to have overlooked.

Most persons are agreed that the fire clay bed lies above what is known as Maxville limestone, and is separated from it by an unconformity, and this relationship is also recognized by the practical clay miner, who in prospecting for fire clay follows the top of the Maxville limestone outcrop.

This position of the clay above the unconformity has led most people to class the fire clay as post-Mississippian and probably Pottsville.

Miller (Ref. 23) has, however, called attention to an occurrence of "flint clay" near Blairs Mill, Rowan County, which is overlain by limestone of Mississippian age, and has suggested on the basis of this evidence, the details of which are given under Rowan County, that the flint clays are of Mississippian age.

While his argument appears weighty on first thought, there are two points opposed to it which cannot be ignored.

Firstly, the so-called flint clay at Blair's Mill is not such, but is a clay of low refractoriness, and secondly so far as can be ascertained no limestone has been found above the fire clay in any of the hundreds of drill holes that have been put down in Greenup, Carter, Rowan or Elliott counties. All this evidence then tends to make the clay of post-Maxville age.

The other point to be considered is the unconformity between the fire clay and the Pottsville conglomerate, for there is no doubt that such a structural condition exists. We might assume that the clay was accumulating in basins on an undulating surface, while the Pottsville conglomerate was being laid down in another area to the northeast, and that as the currents which deposited this coarse pebbly sandstone spread over the area where the Olive Hill clays occur, that they caused some

erosion of the overlying shales, and of some of the fire clay. Indeed in places the fire clay is entirely wanting.

I am also informed by Dr. David White of the United States Geological Survey that the fire clays carry a flora which has been determined to be of Pottsville age. A specimen collected by us from the shale overlying the fire clay in the Harbison-Walker mine at Soldier has been identified by Dr. White as *Lepidodendron obovatum*, which is upper Pottsville. This shale lies conformably on the fire clay, and in many places is separated from the Pottsville conglomorate by a disconformity.

This evidence would therefore seem to place the clay in the Pottsville division of the Pennsylvanian.

Comparison has been made by some of the Olive Hill, Ky., flint clays, and the Scioto Furnace, Ohio flint clays, the assertion being made that they belong to the same deposit.

Fig. 40. Conglomerate below fire clay on ridge south of firebrick.

While there was no opportunity to make an exhaustive study of the Ohio occurrences still a visit to one of the large mines there brought out the fact that the Scioto clay reminds one more of the semi-hard Kentucky clay, than the flint clay, and moreover there is above the clay a peculiar bed of lean ore not noticed in the Kentucky district. There is, too, at a lower horizon than the clay a peculiar conglomerate containing large

and more or less angular fragments of what appear to be quartzite, but which when examined under the microscope look like a silicified fossiliferous limestone.

This same type of rock is found a little below the level of the fire clay beds, which outcrop on the ridges south of Firebrick, Lewis County. Nothing like it was observed in any of the mines of Carter or Rowan counties.

Boyd County

Boyd County is underlain entirely by rocks of the Pennsylvanian system, with the exception of a narrow strip of alluvial deposits along the Ohio River.

Of the Pennsylvanian rocks, the Conemaugh series forms the surface in that portion of the Big Sandy drainage area south of Catlettsburg. (Miller, Ref. 23). It shows a prevalence of red and purple shales which should be looked into by those interested in the manufacture of clay products. The other Pennsylvanian formations forming the surface belong to the Allegheny series.

Underlying the Allegheny series is the Homewood sandstone, regarded as the top of the Pottsville, which outcrops in the valleys.

Shales of Allegheny Series. The Allegheny series contains deposits of shale, which at times appear to be of promising character for the manufacture of products made from red-burning clays. Unfortunately time was not available to undertake a detailed study of these.

Plastic Fire Clay of Allegheny Series. The most important clay resource of the Allegheny formation is the plastic fire clay associated with the Vanport or Ferriferous limestone.

According to Phalen (Ref. 25, p. 113), the fire clay usually lies 10 to 40 feet above the top of the Homewood sandstone (Pottsville), and between coals Nos. 5 (Brookville) and 6 (Lower Kittanning). If coal No. 5 is absent the clay may lie even nearer to the Homewood sandstone.

This clay has been opened and worked in the hills both southeast and northwest of Ashland, and north of Catlettsburg, but some of the most important mines are located in Carter County where the same fire clay also occurs.

The dip of the formations towards the center of the basin causes the clay to disappear near the mouth of the Big Sandy River, and it does not reappear north of Louisa in Lawrence County on the south. From Louisa it outcrops in the hills in the form of a great arc following the outer edge of the basin and coming back to the Ohio river at Ashland. (Ref. 23.)

The plastic fire clay while associated with the Vanport limestone, is sometimes above and sometimes below it. Indeed at some of the mines in Carter County no limestone is found with the fire clay; moreover even in the same mine the thickness of the limestone may vary.

It seems probable that at the horizon of the Vanport limestone there is a clay deposit of variable, and sometimes appreciable thickness, and that certain beds in this deposit may be of refractory character, but that these refractory clay beds do not all occupy the same position in the clay member, nor are they always of great extent.

As proof of these facts we see that the fire clay is sometimes found above and sometimes below the limestone, and the statement of clay miners that the fire clay sometimes becomes impure, necessitating abandonment of the mine, or the driving of a new tunnel into another part of the deposit.

While the Vanport limestone fire clay horizon is usually referred to as a plastic clay, nevertheless it here and there contains pockets of true flint clay, which may be completely surrounded by the plastic material.

The variation which this fire clay may show is illustrated by the following sections:

1. Section at mine in ridge facing Ohio River, 1 mile northwest of Ashland (Crider, Ref. 8, p. 672):

Sandstone	12 ft.
Coal	3 ft.
Plastic fire clay, not used	2-3 ft.
Sandstone	10-12 ft.
White to drab potters clay	5 ft.
Shale with iron ore	4 ft.
No. 2 plastic clay	3½-4 ft
Ferriferous limestone	1-7 ft.
No. 2, white, plastic, fire clay	3-8 ft.
Ganister	.....

Forty feet above the top of preceding section is a thin coal, and 100 feet above the limestone is a ferruginous flint clay which was worked some years ago.

Phalen (Ref. 25, p. 114) gives a section from 1 mile west of Ashland which is somewhat unlike the preceding in that the limestone is missing:

	Ft.	In.
Sandstone, light brown	20+	
Coal	2+	
Shale, light drab	2	
Clay, light brown	6	
Clay, dark drab	1	6
Clay, drab, with scattered iron ore concretions. (Vanport limestone horizon)	2	
Shale, light drab, sandy	1	2
Shale, drab, ranging up to	....	8
Clay, dark drab to black, grading into light drab at middle	1	6
Clay, drab	3	
Flint clay	....	1-4
Clay, drab	3	6
Clay, dark drab, almost black	....	3
Clay, drab	8	

Four feet from the bottom of the lowest layer is a 1-foot bed of light drab flint clay.

There does not appear to be as much demand for the plastic fire clay as formerly, as the flint clay, and semi-hard clay obtained from the Olive Hill district and westward to Morehead are more refractory, although some is still mined to mix with the less plastic clays of the Olive Hill type.

In Boyd County the only plastic fire clay mine in operation at the present time is that worked by the Ashland Fire Brick Company, 1 mile northwest of Ashland. There is here a somewhat extensive deposit of fire clay which has been worked for a number of years. The clay outcrops in the ridge facing the Ohio River, and above the Homewood sandstone. Several tunnels have been driven into the hill. The section exposed at the opening being worked in the summer of 1921 was:

Coal (No. 6?)	3 ft.
Covered	20 ft.
Sandstone and sandy shale	2-4 ft.
Pottery clay	4 ft.
Vanport limestone	2½-8 ft.
Fire clay, average (Range 4-14 ft.)	10 ft.
Very sandy shale, called ganister	.....

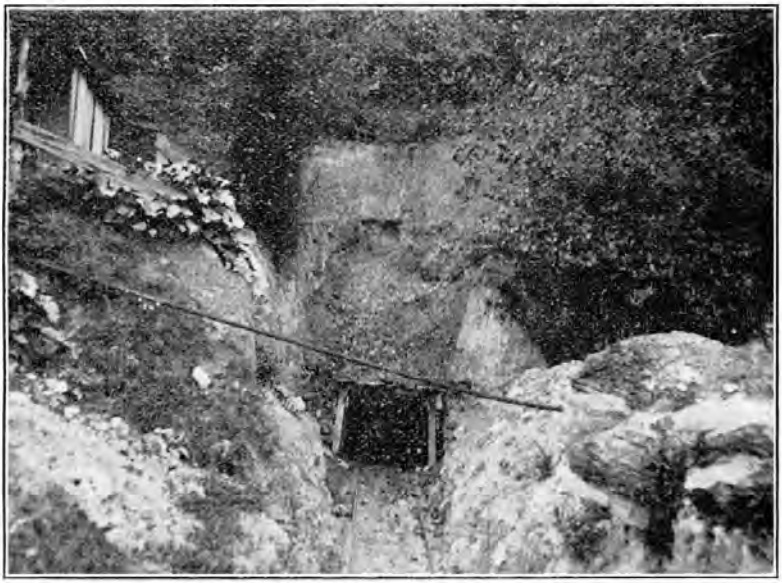


Fig. 41. Entrance to mine of Ashland Fire Brick Company, 1 mile northwest of Ashland.

Fusion tests which have been made on the clays from this mine shows that the refractoriness ranges from cone 30-33, although the lowest bench sometimes drops to cone 29. Cone 31 would perhaps be an average for the bed.

In the next ridge to the northward along the river the same plastic fire clay horizon is found, and up to 6 or 8 years ago Chas. Taylor and Sons Company of Cincinnati bought considerable clay from a mine located near Amanda Station.

The same clay was at one time worked by the O'Kelly Brick Company in East Ashland.

Crider (Ref. 8, p. 672) states that near Cliffside Park, between Ashland and Catlettsburg, the plastic fire clay was former-

ly used by the Weaver Pottery Company, but that here it overlies the Vanport limestone.

Pottsville Fire Clay. Below the Homewood sandstone there is a clay associated with coal No. 4 (Upper Mercer Coal). This coal and its underclay outcrop in the eastern part of Ashland, and in 1905 was first utilized by the O'Kelly Brick Company of Ashland (Phalen, Ref. 22), but the firm is no longer in operation. The same clay is said to occur on Catletts Creek.

Floodplain Clays. The most important of these are found underlying the terraces bordering the Ohio River, and have been utilized in the manufacture of common brick. They are apt to be somewhat sandy.

Clay Working Industry. The clay products produced in Boyd County at the present time include refractory and common brick. Pottery was formerly manufactured also.

Ashland Fire Brick Company. This company has two plants at Ashland. One of these is the old plant of the Clinton Fire

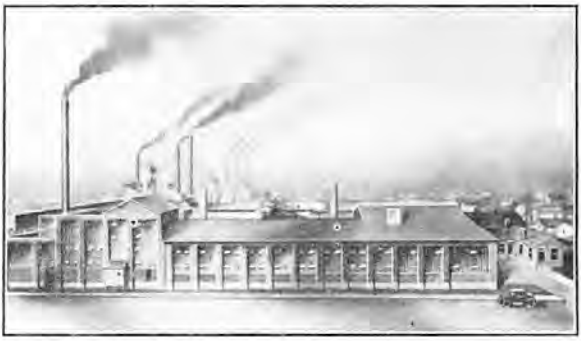


Fig. 42. Ashland Fire Brick Company, Ashland.

Brick Company, built in 1890, and taken over by the present firm in 1900. This has a daily capacity of 20,000 brick.

The other plant, which was erected by the Ashland Fire Brick Company in 1886 has a daily capacity of 40,000 brick.

At the larger plant the semi-hard and flint clays which came from the mine at Hayward, Carter County, are dumped in piles where they are allowed to weather. Some plastic clay from the company's mine northwest of Ashland is also used.

All of the clays are put through a dry pan and then screened. That which is to be used for standard shapes is tem-

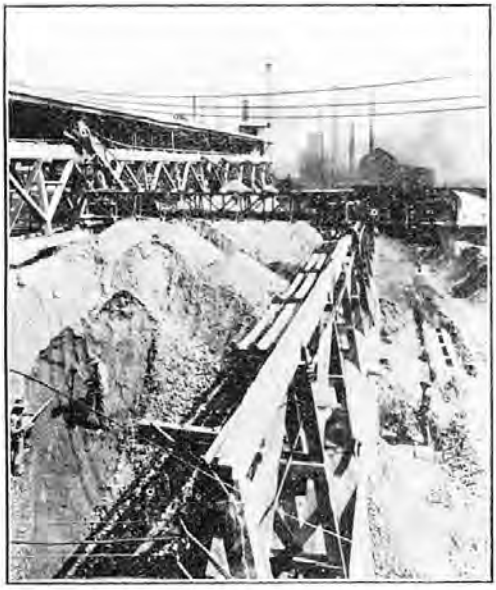


Fig. 43. Weathering clay, Ashland Fire Brick Company, Ashland.

pered in a pugmill and molded in a stiff-mud machine, while clay for special shapes is tempered in wet pans and molded by hand.

The different grades are of course made of different mixtures of hard and plastic clay, and grog.

The standard brick are dried in tunnels at a temperature of 200°F., while the hand-molded shapes are dried on floors. Tracks for the cars lead from the drying department to all the kilns.

The plant is equipped with 12 circular down-draft kilns and 2 rectangular ones. Natural gas is used as fuel. No pyrometers or cones are used at the present time, but a recent cone test bent over No. 13 in top of the kiln.

The two grades of brick produced are known as the Crown and Savage. The two following analyses of the company's best

grade of brick, and other tests of their product have been kindly supplied to us by the firm:

	I.	II.
Silica	57.28	57.20
Alumina	38.50	37.78
Ferric oxide	2.80	2.84
Lime	.42	.86
Magnesia	.32	.04
Alkalies	1.10	.48
Titanic oxide	.....	.92
	100.42	100.12

Specific Gravity

Ashland Crown steam pressed process 2.20; 2.19; average..... 2.20
Ashland Savage hand molded and hand pressed 2.63; 2.59; aver. 2.61

Softening Temperature

High duty requirements—cone	31
Ashland Crown steam pressed process—cone	32-33
Ashland Savage hand molded, hand pressed—cone	33

End Cold Crushing Strength in Total Pounds

	Ashland Crown	Ashland Savage
Test No. 1	24,450	10,000
Test No. 2	26,500	11,650
Test No. 3	24,500	12,400
Average	25,150	11,350

Spalling

The bricks were heated one hour at 1350 degrees centigrade, plunged into five inches of running cold water for three minutes, air dried for five minutes and returned to the furnace. The average loss of the Crown after 10 immersions was 6%, after 20 it was 12%, and after 30 it was 19%. The Ashland Savage lost none after 10 immersions, 3% after 20, and broke on the 28th losing 28%.

Slag Action

Cavities were drilled which were filled with open hearth slag at 1350 degrees C. The action continued for two hours after which the brick were cut through the centers of the cavities and the penetration was measured.

	Ashland Crown	Ashland Savage
Depth of penetration	.00 inches	.10 inches
Depth of pentration	.00 inches	.15 inches
Average penetration	.00 inches	.13 inches

Reheating Test

After heating for 5 hours at 1400 degrees C., the following linear changes were noted upon cooling:

	Per Cent
Ashland Crown expanded	.45
Ashland Savage expanded	.18
Allowable expansion for high duty brick	1.
Allowable contraction	1.5

Load Test

When the bricks were heated on end at 1350 degrees C. for 1½ hours under a pressure of 25 pounds per square inch, the following compressions were noted (Standard high duty test):

	Ashland Crown	Ashland Savage
Original dimensions	8.84x4.33x2.45	9.0x4.5x2.53
Final dimensions	8.78x4.31x2.44	8.87x4.5x2.53
Compression	0.06 inches	0.13 inches
Per cent compression	.68 per cent	1.44 per cent

Allowable compression, 3% and in many cases the limit is 5%.

Porosity

Ashland Crown	14.25%
Ashland Savage	18.55%

Water Absorption

Ashland Crown	6.48%
Ashland Savage	9.28%

Some time ago we desired to get the shrinkage of our flint and semi-flint Kentucky fire clays as taken from the mines and after being weathered. The results of these tests which were also made at the Mellon Institute, are as follows:

SHRINKAGE TEST.

	Drying Shrinkage %	Burning Shrinkage %	Total Shrinkage %
Flint clay (from mine)	2.01	5.39	7.40
Flint clay (weathered)	2.66	5.47	8.13
Semi-flint clay (from mine)	1.74	4.43	6.17
Semi-flint clay (weathered)	3 51	5.47	8.98

These tests show that generally longer weathering and larger amount of water are coupled with greater shrinkage.

Means and Russell Iron Company. This firm has a plant at Bellefonte at which common bricks are made by the soft-mud process. The clay is obtained from a flood-plain deposit.

J. J. Gate and Company. This company also makes common red building brick, using a clay obtained from the river bottom of the Ohio.

O'Kelly Brick Company. This firm was formerly engaged in the mnaufacture of common brick. It is no longer in operation and the machinery is being removed.

Breathitt County

Breathitt County is underlain by Pennsylvanian formations, and so any materials of value to the clay worker are to be sought chiefly in this system of rocks. Aside from this there is the possibility of finding some flood-plain clays along the North Fork.

The Pennsylvanian might also possibly yield under clays of coal beds.

A reconnaissance was made along the Louisville and Nashville Railway, chiefly to ascertain whether any clays or shales of commercial value were associated with the coal beds.

Elkatawa. The mine of the Breathitt County Coal Company, shows from 18-24 inches of soft gray slightly gritty clay in the roof. It is somewhat iron stained and contains thin streaks of coal.

The material (Lab. No. 2457) has moderate plasticity and fires to a red brick, but it is not refractory.

It was not possible to obtain a sample of the underlying material.

Jackson. The Davis Coal Company, whose mine is located ¾ mile north of Jackson on the Louisville and Nashville Railway is working the No. 3 coal. The roof is a very hard shale, and the floor of the coal is sandstone, so no sample was collected.

On the west side of the Louisville and Nashville Railway, about 150 yards north of Jackson, a good bed of shale is exposed. The section shows:

	Ft.	In.
Sandstone	5	
Gray laminated shale	12	
Siliceous ironstone	0	2
Gray shale	0	4
Shale with concretions	0	8
Soft red-brown shale	0	3
Greenish sandy shale	1	
Sandstone	3	

Shale.

The 12-foot bed of shale weathers to small flakes. It is black when fresh, gray when weathered, slightly gritty and contains scattered flakes of muscovite.

The shale (Lab. No. 2458), when ground up and mixed with water is not highly plastic, and yet it is sufficiently plastic to work. It fires to a bright red, but has to be burned slowly in order to prevent black coring. It could be used for common brick.

Haddix. The three coal mines located about Haddix all have sandstone overlying the coal, and a hard shale of probably red-burning character below.

About 1½ miles southwest of Haddix in the Louisville and Nashville Railway cut, the section shows:

Soil	.....
Sandstone	5 ft.
Laminated shale with concretions	8 ft.
Coal	⅓ ft.
Clay with sand and concretions	3 ft.
Coal.	

The clay and shale do not appear to be of promising character.

Riverside. About 200 yards west of Riverside on the O. and K. Railroad, and on the property of the K-U Land Company there is a deposit of clay whose section shows:

Soil	3 ft.
White sandy clay	5 ft.

The clay is white, plastic, and very sandy, but tough when wet. It has scattered limonite stains.

The clay is interesting partly because although very sandy it possesses excellent plasticity, and partly because of its firing qualities.

The following tests of this clay (Lab. No. 2459) represent its character:

Lime carbonate	None
Working quality	Good
Plasticity	Very good
Air shrinkage (linear)	7.5%
Color after firing	Buff
Steel hard	950° C.

	Fire Shrinkage	Absorption
	%	%
950° C.	0.	18.5
1090° C.	4.5	7.9
1130° C.	6.0	5.0
1250° C.	7.5	2.0

This clay shows a curiously high plasticity in spite of its sandy nature. It would seem to be a good material for making face brick, and could be also used for common brick. It burns to a good buff color.

Gauge. Easton (Ref. 10, p. 766) notes a clay overlying the Dean coal, from Shock Branch, 1 mile above Gauge. The material is said to have 5 per cent fire shrinkage, to be nearly vitrified at cone 11, and to burn to a buff color.

Carter County

Most of the surface formations of Carter County are of Pennsylvanian age, the Pottsville conglomerate being an important one. In the eastern part of the county the Pottsville dips below the surface so that the rocks of the Allegheny series are the prominent ones.

The Mississippian formations are exposed in narrow belts, notably in the valley of Tygart Creek and its tributaries. There are also smaller areas as in the valley of Big Sinking Creek, around Grahn, and between Olive Hill and Grayson.

Since the important beds of flint and semi-flint fire clays occur at the contact of the Pottsville and Mississipian, they will be found outcropping only where the former has been cut through by erosion.

They are not found east of Aden, and from there eastward dip rapidly below the surface. Crider (Ref. 8, p. 659) states that at Denton the oil drillers struck 10 feet of flint clay at a depth of 625 feet below the surface. Between it and the Pottsville conglomerate above there was 15 feet of blue shale, and immediately below it there was limestone.

The plastic fire clays of the Vanport limestone horizon are caught in the hill tops just east of Hitchins about 230 feet above the railroad track, and the same bed is mined south and east of Denton.

Shales of probable Pennsylvanian age, and worthy of detailed investigation are seen between Olive Hill and Grayson and they should also be looked for in the region around Kilgore.

Allegheny Clays. An important deposit of plastic fire clay occurs at the horizon of the Vanport or Ferriferous limestone. The material may underlie or overlie the limestone, while at other times the limestone is absent. In some places more than one bed of fire clay appears to be present. Lenses of flint clay are occasionally found within the plastic fire clay. Indeed it seems probable that there is not one distinct fire clay bed throughout the district, but instead several locally refractory portions of a rather extensive deposit of plastic clay and clay shales. This view is held partly because the relation of the fire clay to the limestone is not always the same, and partly because in some mines the fire clay may grade into nonrefractory plastic clay.

In refractoriness the clay is not equal to the flint and semi-hard clay found at the base of the Pottsville. It is worked at Ashland, Denton and Hitchins, and has also been mined in the past at other localities. The beds rise to the west, and at the most western point where it is found, viz., Hitchins, the fire clay is near the tops of the ridges. It does not occur either very far to the northward of the line of the Chesapeake and Ohio Railway.

The shale formations of the Allegheny series should be looked into as it seems possible that some of them at least may serve for the manufacture of clay products. Attention is called to one deposit between Olive Hill and Grayson and another at Torchlight, Lawrence County.

Conemaugh. The Conemaugh carries purple and red shales in portions of Lawrence and Boyd counties but no tests regarding their characters are available.

Pleistocene. The alluvial clays underlying terraces along the Ohio River have been used for brick making at Ashland and Bellefonte. No doubt additional ones could be found at other points.

KENTUCKY GEOLOGICAL SURVEY

SERIES VI

WILLARD ROUSE JILLSON
DIRECTOR AND STATE GEOLOGIST

ECONOMIC MAP OF

BOYD, CARTER, & GREENUP

COUNTIES, KY.

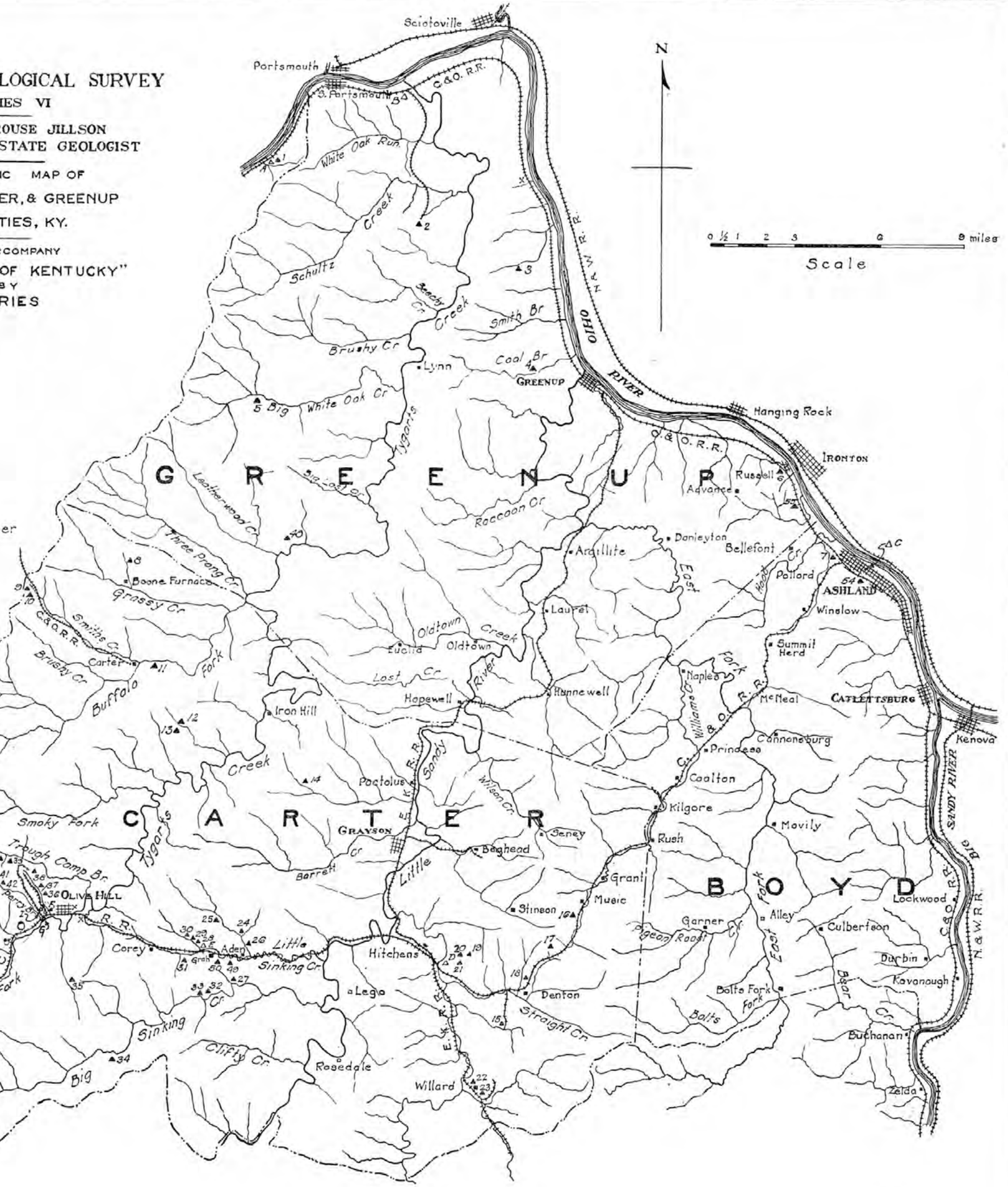
TO ACCOMPANY

"THE CLAYS OF KENTUCKY"

BY

H. RIES

△ Brick Plants
▲ Clay Pits
x Quarries
Glass Sand Crusher



Fire Clay Deposits

The fire clay deposits are described in general from east to west:

Willard. No fire clay mines are being worked around Willard at the present time.

Crider (Ref. 8, p. 662) states that a bed of fire clay rests directly on the Ferriferous limestone, and has been worked at several places, but that the operations could not be successfully continued because of high freight rates.

The section below the Ferriferous limestone is given by him as follows:

Ferriferous limestone.
Thin bed of flint clay.
Thin bed plastic fire clay.
Black shale 8-10 ft.
Thin coal.

He suggests that the black shale could be used for sewer pipe, but gives no tests of its qualities. If it were available for the purpose mentioned it would have to be worked by underground methods.

An analysis of the fire clay given by Phalen (Ref. 25, p. 116) is:

Silica	60.54
Alumina	25.89
Ferric oxide	1.75
Lime	.53
Magnesia	.12
Potash	1.85
Soda	.65
Manganous oxide	.26
Sulphur trioxide	.12
Ignition	7.43
Moisture	2.05
	101.19

Two fire clay mines were formerly in operation at this locality. One on the northern edge of Willard was worked by Dr. H. B. Fraley, the other on the eastern edge of town by the Willard Fire Clay Company.

The following analysis of clay from Fraley's mine has been supplied by C. E. Bales:

Silica	54.48
Alumina	31.96
Ferric oxide	2.80
Lime	.78
Magnesia	.40
Alkalies	.62
Ignition	8.94
	99.98

Denton. The only mines which are being steadily operated in this vicinity are those of the Harbison-Walker Refractories

Fig. 44. Fire clay mine, Harbisson-Walker Refractories Company, southwest of Denton.

Company. These are situated on a private branch railroad about 2 miles south of Denton, on Davies Branch of Dry Fork, and about 200 feet above Denton station.

A narrow gauge steam railway runs from the Ashland Coal and Iron Railway tracks at Denton, to the clay mine, and also to the company's coal mine still farther up the valley.

The material is a slightly micaceous, plastic fire clay, which runs about 4½ feet thick. It grades downward into a

very sandy micaceous clay. Above the fire clay is a thin layer of coal, and this in turn is capped by about 50 feet of impure shales, the lower two feet of which is sometimes found to be refractory. These top shales as a whole are red burning, and contain scattered concretions of siderite and pyrite. Pyrite is also at times found in the fire clay.

There is no limestone lying immediately above the clay here, as is the case in the mines at Ashland, but a bed of it occurs about 100 feet above the clay. A coal bed, said to be the No. 7 coal, lies about 60 feet above the fire clay.

The clay is mined by an entry running south into the hill, and from this cross entries will be driven.

Several other openings have been made in the same clay bed between the present mine and Denton, but the workings are no longer accessible.

J. H. Burdett in 1907 opened a mine one mile east of Denton on the north side of the Chesapeake and Ohio Railway tracks. At the time of our visit the mine was not accessible and the following data are taken from Crider's report (Ref. 8, p. 669):

The opening lies about 50 feet above the level of the railroad, and it is underlain by a massive sandstone. The Ferriferous limestone is absent at the coal horizon, but a coal which outcrops at the level of the railroad track is said by Crider to be No. 4. The section at the mine is:

	Ft.	In.
Coal		14
Black plastic clay	4-6	
Dark, hard, siliceous clay		2.4
Good, No. 2 plastic clay	6	
Sand rock, called ganister	4	

The No. 2 clay may be cut out at times by siliceous boulders. A flint clay is said to occur about 55 feet above the plastic clay.

The clay from this mine has been shipped to Pennsylvania and Ohio. Mr. Burdett, of Ashland, Ky., claims that the clay underlies an area of 3 square miles.

The following analysis of plastic fire clay from the Burdette mine has been supplied by C. E. Bales:

Silica	56.96
Alumina	29 90
Ferric oxide	1.62
Lime	.46
Magnesia	.24
Alkalies	.65
Ignition	10.17
	100.00

This clay is used in the manufacture of fire brick.

The Denton Plastic Clay Company in 1908 opened a mine 200 yards east of Denton on the north side of the Chesapeake and Ohio Railway and about 200 feet above the track. It is not being worked at present, and has not been for several years.

Crider (Ref. 8, p. 668) gives the section as:

Light gray shale.	Ft.	In.
Laminated micaceous sandstone	6	
Dark clay	4	
Coal		10
Black plastic clay, not worked	5	
Dark hard siliceous clay, not used		4
Plastic clay with silica boulders	8	
Ganister	4	

It is said to be at the Ferriferous limestone horizon, although there is no limestone present.

Hitchins. General Refractories Company. This Company has deposits of plastic clay which lie near the top of the ridges about 1½ miles east of Hitchins. A standard gauge track is laid from the plant up to the mines.

The fire clay, which Crider claims is at the horizon of the Ferriferous limestone lies about 35 feet below the No. 7 coal, about 140 feet above No. 3 coal, and about 240 feet above the works.

The fire clay, which varies from 4-12 feet in thickness, with an average of 6 feet, is very plastic, of gray color with iron mottlings. Near the top the clay becomes grayish black and is overlain by a very thin layer of coal. The clay shows occasional flakes of mica and thin crusts of gypsum. At one point in the bed the clay also showed pockets of oolitic material, the oolites

Fig. 45. Open cut in plastic fire clay, General Refractories Company, Hitchins.

being about 1/32 inch in diameter. Lenses of flint clay are occasionally found in the plastic clay, and these may be as much as 8 feet long and 2 feet thick. This flint clay is a hard, grayish-black clay, with conchoidal fracture and spots of a carbonaceous matter.

The floor of the fire clay bed is a sandy, micaceous clay, while overlying it there are ferruginous shales, with thin layers of sandstone. It is interesting to note that in the overlying shales there are small pockets of flint clay of excellent refractoriness, but none of them are sufficiently large to work.

A part of the fire clay has been obtained from open cuts, run around the face of the hill, the overburden being removed with a steam shovel. From these open cuts tunnels are driven into the ridge where the overburden is heavier and the clay is mined from these.

Several old workings lie in another ridge about ⅛ mile northwest of the present workings.

The plastic fire clay can be traced eastward towards Denton, but it is not found west of Hitchins as the rise in the beds would bring it above the tops of the ridges in that direction. The following section given by Crider (Ref. 8) is that seen in a hill east of the fire brick works and near the "Blue Jay" coal

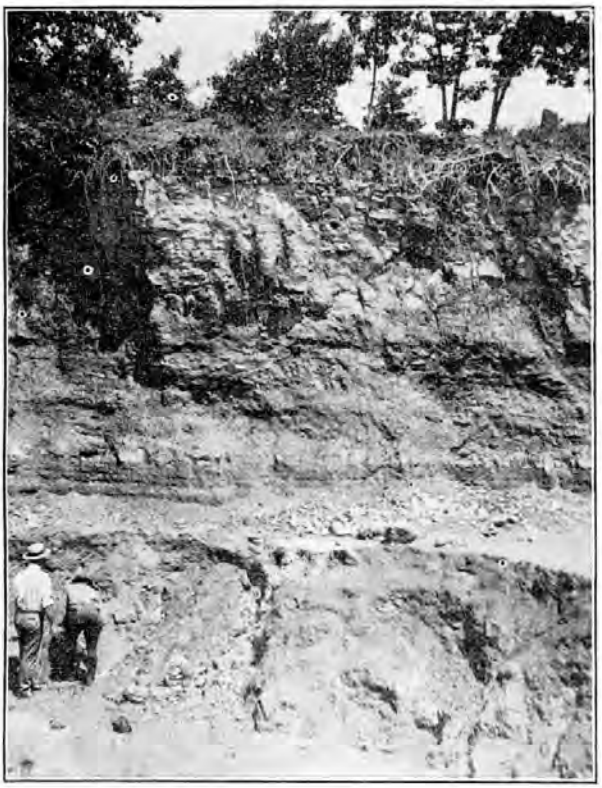


Fig. 46. Pit of General Refractories Company, Hitchins. Shows impure shales overlying fire clay.

mine to the clay opening at the head of the branch. The entire thickness of the section is about 300 feet:

		Ft.	In.
28	Crest of high hill.		
27	Covered. Ferriferous limestone comes near base	70	
26	Plastic clay containing thin irregular pockets of flint clay	25	
25	Gray laminated shale which weathers to a bluish clay	2	
24	Gray plastic clay with two inches of dark clay in the center	1	
23	Black shale		21
22	Coal		13
21	Irregular bodies of stratified clay	4	

20	Pale drab stratified fire clay	.....	20
19	Dove colored fire clay with streaks of iron oxide	.....	12
18	Dove colored fire clay, uniform in color	.....	18
17	Gray micaceous sandstone about	15	
16	Covered	.....	
15	Sandstone	.....	
14	Shale	3-4	
13	Coal	.....	1
12	Draw slate	1	
11	Coal	.....	21
10	Bone	.....	3
9	Coal	.....	14
8	Fire clay	.....	
7	Shale	25	
6	Sandstone changing to shale at same horizon	50	
5	Gray shale	25	
4	Coal	.....	3
3	Sandstone, hard on bottom and shaly on top..	6	
2	Black shale	20	
1	Sandstone.		

"The fire clay occurring from 18 to 21 inclusive is the most promising horizon of the section. At horizon 26 is a deposit of laminated, micaceous shale which contains irregular blocks of flint clay. In places it occurs in kidney-shaped forms. The color is not uniform, but shows finely stratified lines of white, light gray to dark gray sand in the clay."

Crider further believes that there is also a possibility of getting the Olive Hill flint clay below the surface at Hitchins, because a bed 10 feet thick was struck in one of the oil wells at Denton, at a depth of 625 feet below the surface. Mississippian limestone underlay the fire clay, while above it there was 15 feet of blue shale, overlain in turn by the Conglomerate sandstone. The rise of the strata to the west would bring the Olive Hill flint clay horizon to within about 350 feet of the surface at Hitchins. Crider expresses the belief that if flint clay of good quality and 7 to 10 feet in thickness could be found below Hitchins, that it would be more economical to the mine even at that depth, than it would be to haul it from the Olive Hill district. Its presence or absence could be determined by means of a core drill.

Crider gives the following analyses and tests of the clays from the Hitchins property. They were made by J. M. Knote, and the comments following are also his:

	Loss on Ignition	Silica	Oxide Iron	Oxide Aluminum	Oxide Calcium	Oxide Magn.	Titanic Acid	Alkalies	Fusion Cone	
1.	12.24	53.30	.71	30.88	.50	.08	2.21	.12	34	3290° F.
2.	8.16	58.90	1.71	26.28	.45	.08	1.28	3.40	24½	3092° F.
3.	10.32	56.46	1.71	27.89	.60	.20	1.48	1.45	28	3182° F.
4.	8.48	64.38	.71	23.54	.50	.08	1.51	.99	31	3182° F.

(1) "Flint clay from bottom seam. Shrank from 12 to 11 1/10 inches on burning. No shrinkage after cone 9. An excellent clay and while a little higher in silica than those of Olive Hill, it should make very good brick. It is as good as the best Missouri, Pennsylvania and Maryland flint clays."

(2) "Plastic clay, shrank from 11 to 12 inches on drying and to 10½ inches on burning. A very plastic and strong bond clay. It dries with a normal shrinkage and burns to a dense strong body at cone 3 and remains thus without change to cone 11. It would doubtless show little change up to cone 22-25. Its burning shrinkage is normal. The clay is as plastic and strong as any but the exceptional fire clays. It vitrifies 3 or 4 cones lower than the Maryland clays, but about the same as most Pennsylvania clays. The Missouri clays are much more porous at cone 11. In refractoriness it is just about the same as the best Savage Mountain clay or Pennsylvania clays. I consider it a very good bond clay.

(3) "Plastic clay. Shrank from 12 to 11 2/8 inches on drying and to 10½ inches on burning. Nearly out at cone 3, all out at cone 7-9. Similar to No. 2 in every way."

(4) "Flint clay. Shrank from 12 to 11 2/10 inches. All out at cone 9. This clay is a second grade flint clay and while of probable value for second grade brick, it is not as valuable as clay No. 1."

The plastic clay has a fusion point of cone 30-31.

The plant of the General Refractories Company is located in the valley, just east of Hitchins and on the north side of the Ashland Coal and Iron Railroad Company's tracks. The works, which has a daily capacity of 75,000 brick, was built in

1912, is of fire proof construction, and the machinery is all operated by electricity. Coal for fuel is obtained from a mine in the No. 3 coal bed, located along the track leading up to the fire-clay deposits.

The raw materials used are plastic fire clay from the deposits at Hitchins, and flint and semi-hard fire clays from the company's mine near Grahn.

The clay is all ground in dry pans, screened, and then tempered in pugmills. Standard brick are molded in a stiff-mud machine, with circular cutter, and subsequently repressed. They are dried for 3 days in concrete drying tunnels.

Special shapes are molded by hand and are dried on concrete floors, one of which is on top of the tunnel dryers, and the other at the level of the floor of the building. The drying tunnels are heated by waste heat from the kilns, the temperature of this when entering the tunnels being 200° F. The lower floor is heated by exhaust steam.

There are 16 down-draft circular kilns, whose diameter is 36 feet, with a stack for each pair of kilns. Firing requires 9 days, and it is said that cone 12 is bent over in the bottom of the kilns. The total shrinkage of the clay is 9/10 inch per foot.

The chief product of the plant at present is the Carter or best brand, and this is used for hot blast stoves.

Music. Plastic fire clay has been mined on Norton's branch near Music by Messrs. Hatcher and Stewart of Ashland, but none has been shipped for several years. They report that the clays show considerable irregularity in quality when followed from one place to another.

The Kentucky Gem Coal Company formerly worked a plastic fire clay at Norton's Branch, two miles west of Rush. The clay was about 9 feet thick. Several entries were driven, but each one finally ran into hard rock, so that the mine was abandoned. This clay they state was about 100 feet below the No. 7 coal.

Crider (Ref. 8, p. 671) notes that a No. 2 plastic fire clay was opened on the Lexington and Carter County Mining Company's property just north of the Ashland Coal and Iron Company's railway. It is said to be 9 feet thick, and to rest on

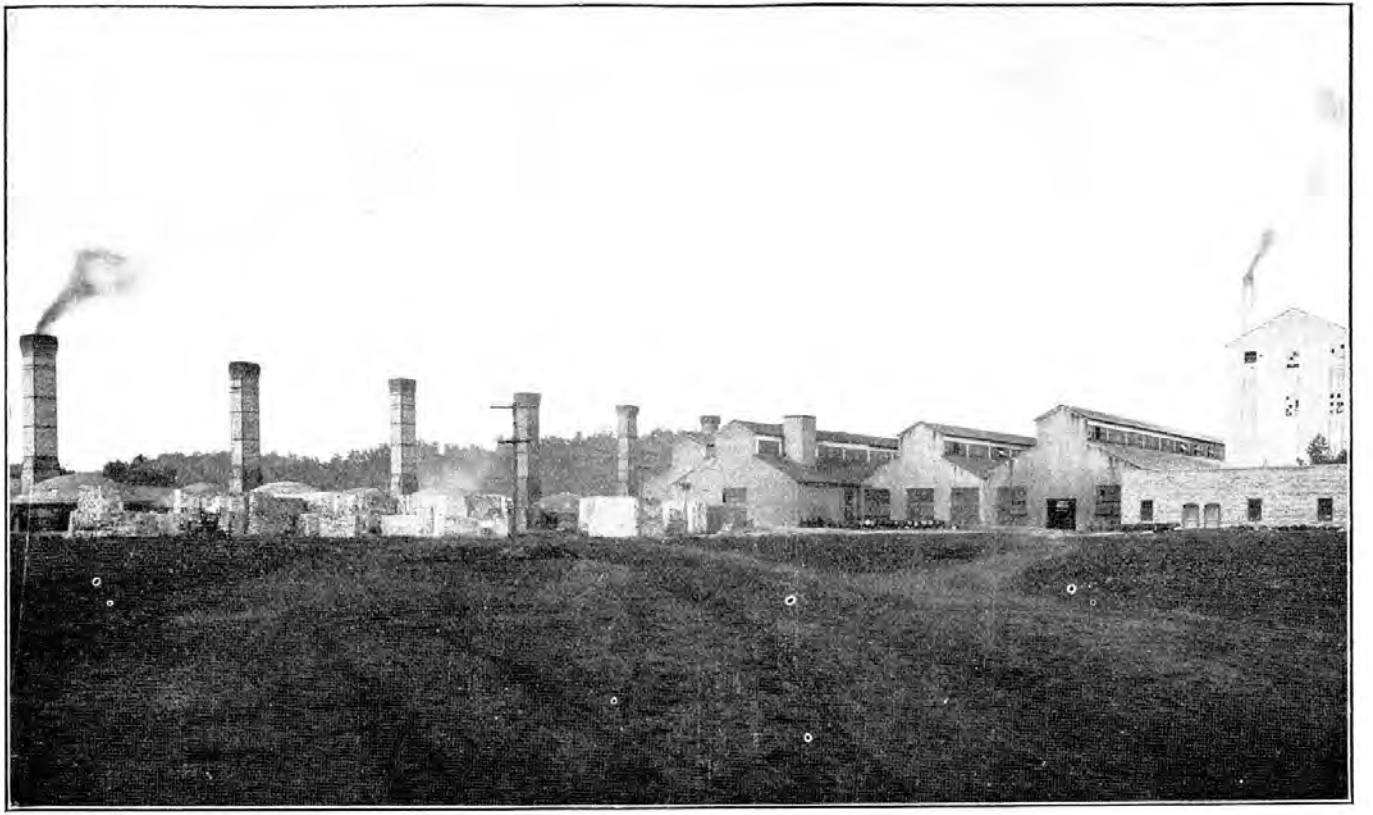


Fig. 47. General view of plant of General Refractories Company, Hitchins.

ganister rock like the clay at the Burdette mine east of Denton. There is a thin bed of coal near the top of the clay.

A flint clay is reported to have been formed 2 miles north of Music, but this is probably one of the lenses of this material which are sometimes found associated with the plastic fire clay.

Aden. Kerns Mining Company. The mine of this company is on land leased from J. M. Saulsberry, and is located 300 feet west of the station on the north side of the Chesapeake and Ohio Railway. It was not in operation during 1921. At this mine the tunnel has been driven about 300 yards and shows the following section:

	Ft.	In.
Sandstone	.....	
Blue shale	4-10	
Coal (sometimes in the shale)	.....	14
No. 1 flint clay	⅔-1	
No. 1 semi-hard clay	2-3	
White, sandy, iron stained clay.		

Mr. C. E. Bales has supplied us with the following analysis of gray plastic clay from Aden:

Silica	51.40
Alumina	31.88
Ferric oxide	1.92
Lime	.32
Magnesia	.14
Alkalies	.56
Ignition	12.80
	99.00

The material is used in the manufacture of fire brick. This is the most easterly mine in flint clay. Between Aden and Grahn the section at the Chesapeake and Ohio Railway tunnel (Ref. 8, p. 649) shows:

Weathered shale	7 ft.
Coal	1 ft.
Poor fire clay	11 ft.
Iron ore	1¼ ft.
Flinty limestone in beds 6 ins. to 3 ft. thick.	

Louisville Firebrick Works. This company's mine is located about 1 mile west of Aden, on the south side of the Chesapeake and Ohio Railway. It adjoins that of the General Refractories Company, and both mines have the same air course. The section is.

Pottsville conglomerate.	
Black shale	8 ft.
Black plastic clay	1 ft.
Flint clay	0-1 ft.
Semi-flint clay	4-5 ft.
Red clay	.....

Neither the black plastic clay nor the flint clay extend throughout the entire mine, and where absent the semi-flint clay is correspondingly thicker. We are informed that since visiting this locality the fire clay has passed into a sandstone.

General Refractories Company. The mine of this company is located on the north side of the Chesapeake and Ohio Railway, about 1 mile west of Aden, and adjoining the mine of the Louisville Firebrick Works.

A drill hole record supplied by the General Refractories Company gives the following section at this mine:

	Ft.	In.
Surface material	3	....
Sandstone	22	....
"Slate"	1	....
Sandstone	6	....
Sandy No. 4 clay	0	6
Flint clay	3	....
Semi-hard clay	2	4
Pinkeye and yellow ocher	1	2
Limestone.		

Miscellaneous Occurrences. The following additional notes on the occurrence of fire clay in the vicinity of Aden are given by Crider (Ref. 8, p. 650).

On the P. F. Maddix land, 1 mile south of Aden, and near the ford across Big Sinking River, a 60-foot tunnel driven into the hill showed:

Conglomerate.	
Coal	1¼ ft.
Fire clay (15-24 inches of this is flint)	8 ft.

The most eastward extension of the clay and limestone noted by Crider is on the Big Sinking River, on the south side of the stream, and just above the mouth of Hall's Branch.

A number of fire clay openings have been made on the Big Sinking River south and southeast of Olive Hill, but most of them are remote from transportation.

Another locality noted by Crider (Ref. 8, p. 650) is the Prater Mine on Dry Fork, 2 miles north of Aden, where in an entry driven 180 feet into the hill the section showed:

Shale roof	2 ft.
No. 4 fire clay	2 ft.
Coal	2 ft.
Flint clay	2 ft.
Semi-hard clay	2 ft.
Pinkeye	2 ft.

Fig. 48. Entrance to fire clay mine at Grahn. The roof is Pottsville conglomerate, which rests directly on the clay.

Louisville Fire Brick Works. This company has two fire brick plants at Grahn and has also driven several tunnels into the fire clay deposits, but all of these are not being worked at the present time.

Two openings have been made on either side of a ravine located about 1/4 mile north of the works, and the one on the south side was being worked in 1921. At these two mines the

Pottsville conglomerate rests directly on top of the fire clay at many points in the mine, although occasionally shale and another conglomerate come in between them.

These two mines are known as No. 1 and No. 2, and the generalized section is:

Pottsville conglomerate sandstone (exposed)	40-80 ft.
Conglomerate with pebbles of clay, siderite and shale	0-1½ ft.
Black shale, with smooth, shining surfaces, along the bedding planes	0-5 ft.
No. 2 plastic clay	0-2 ft.
Flint clay	0-2 ft.
Semi-hard clay	3-5 ft.
Pinkeye clay	1-3 ft.
Green or yellow clay shale	
Limestone.	

The geologic relationships are so different here from those seen at other mines as to deserve special mention.

The Pottsville conglomerate as will be noted from the above section rests in places directly on the clay, a fact not noted elsewhere. It is a sandstone containing irregular patches and streaks of quartz pebbles, the latter at times reaching the size of a pigeon's egg.

Immediately under the Pottsville conglomerate, and sharply separated from it are thin lenses of a conglomerate, which reach a maximum thickness of 18 inches, and which in the mine could be traced for a distance of 200 to 300 feet. This conglomerate, which is composed almost entirely of pebbles, has a matrix of micaceous sand, and the pebbles which vary from round to angular consist of sandstone, clay, black shale and siderite concretions, but there are none of quartz. In places this conglomerate rests on black shale, in others, where the shale has been worn away it rests on the flint clay, the pebbles of the conglomerate extending into the clay. There is consequently a disconformity between the conglomerate and the black shale.

The black shale, which in places has been eroded, contains concretions of siderite and also pyrite, and the latter may be also found in the flint clay. This black shale ranges from 0-18 inches in thickness.

The fire clay, which is mostly flint clay towards the mine entrance, but mostly semi-hard in the mine, averages about 4 feet in thickness.

In the inactive mine, on the north side of the ravine, the Pottsville conglomerate forming the roof shows small stalactites of lime carbonate, formed by the water seeping through the Pottsville.

At the south end of the workings of Mine No. 1, the fire clay appears to be bent into a monoclinal fold. This has also involved the overlying shale and sandstone, to such an extent that portions of the sandstone have been forced into the shale in dike-like bands. No coal was seen in this mine.

In a mine which Crider describes (Ref. 8, p. 648) as being located on the north side of Grassy Fork, ¼ mile up stream from Grahn station, he states that the limestone outcrops on the south side of the creek, and that in places the bottom of the clay is very uneven, due to the irregularity of the underlying limestone surface, because where there are sink holes like depressions in it these are filled with clay, thus making the latter doubly thick. In places, it is stated, the limestone may rise and almost cut out the clay. In this mine too the conglomerate at times rests directly on the clay, but at others is separated from it by a thin bed of shale with a thin coal bed (0-8 inches) at its base.

The following tests of clays from the mines of the Louisville Fire Brick Works at Grahn were kindly supplied us by the company:

	No. 1 Flint Clay Bone Branch Mine	No. 2 Clay No. 2 Mine	No. 3 Clay
Silica	44.00	45.72	53 00
Alumina	39.96	39 23	22.64
Ferric oxide	2.20	1.75	11.20
Lime	.30	.40	.68
Magnesia	tr.	tr.	.34
Alkalies	.24	.30	1.28
Ignition loss	13.72	12.80	11.08
	100.42	100 20	100.22

Fig. 49. View of Louisville Fire Brick Works, Grahn.

PHOTO BY W. R. JILLSON

Plasticity	Poor	Fairly good	Good
Air shrinkage, in. per ft.	3/16	¼	½
Fire shrinkage, in. per ft.	13/16	¾	⅝
Color at 1315° C.	Cream	White	Brown
Cone of fusion	34	34	20

As previously stated the Louisville Fire Brick Works has 2 plants at Grahn, but only one was running in 1921.

The clay is hauled to the mines in dump cars drawn by mules.

For standard-sized brick the clay is run through dry pans, screened and then after moistening it is molded in a semi-dry press machine, and repressed. For hand-molded shapes the clay is tempered in a wet pan, and then transferred to the molding table.

The two plants are together equipped with 15 circular down-draft kilns, and firing takes 5 to 6 days. No pyrometers or cones are used. The two plants have a combined capacity of 60,000 9-inch brick daily.

Olive Hill. This locality was the site of the first flint fire-clay mining operations in eastern Kentucky, and also of the first fire brick plants erected in the flint clay district, as noted in Chapter VI.

At present there are two fire brick plants in active operation, at Olive Hill, both of them being located north of the town, and on the north side of the valley.

One of these is the plant of the Harbison-Walker Refractories Company, and the other that of the General Refractories Company, which in 1909 took over the property of the old Olive Hill Fire Brick Company and expanded it. Both companies have mines located several miles north of Olive Hill, and these are the nearest active ones to the railroad at present.

In former years there were several mines operated much nearer town. One of these was the famous Burnt House Mine described under "Inactive Mines" below. The active operations will be taken up first.

Harbison-Walker Refractories Company. The mines which this company is at present working are located about 4 miles north of Olive Hill in the valley of Trough Camp Branch. They

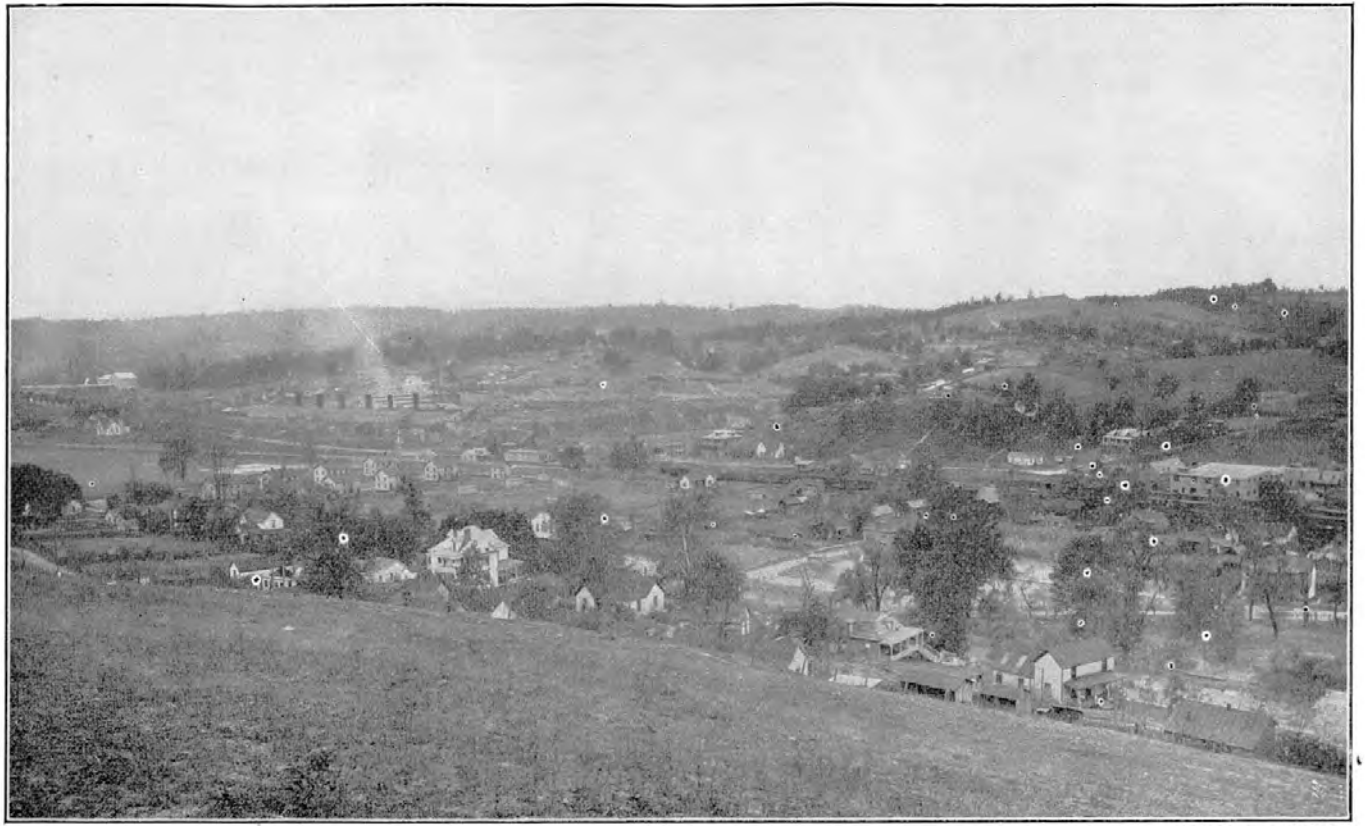


PHOTO BY W. R. JILLSON.

Fig. 50. General view of Olive Hill.

are known as the Quall Mine and the Old Garvin or Mud Lick Mine, the former being situated on the north side of Trough Camp Creek and the latter on the south side.

The narrow-gauge road leading up to the mine passes through the hill from Henderson's Branch to Trough Camp Branch, a distance of 1300 feet. One-half of this tunnel driven from the Trough Camp side was in clay, but the balance was cut in shale which cut the clay out.

An extension of the old Garvin or Mud Lick mine is known as the Scott entry. A general section in the deposit is as follows:

Shale or sandstone roof	.....
Coal	0-1½ ft.
No. 2 plastic clay	0-2 ft.
Flint clay	3-6 ft.
Semi-hard clay	3-6 ft.
Pinkeye or sandstone.	
Limestone.	

In the Scott extension of the Mud Lick mine for example the clay is about 6½ feet thick, and consists of both flint and semi-hard, there being but little plastic clay in that mine. The flint clay may be shiny, dull and earthy, or sandy in appearance, and in places pinches out completely, leaving only semi-hard clay. The coal is usually found above the clay and is overlain by shale or sandstone. The No. 2 plastic when present is always below the coal and above the flint clay. Pinkeye usually forms the floor and lies above the Maxville limestone whose outcrop on the hillside below the mine shows a thickness of 60 feet. In some places a sandstone overlies the limestone and on the outcrop may be 15 feet thick.

The Garvin (Mud Lick) mine, (Ref. 8, p. 623), was opened in 1900 and by 1913 the west entry had been driven 1900 feet into the hill. The section in 1913 as given by Crider was:

	Ft.	In.
Sandstone, fine grained	.....	
Black "Huckleberry shale"	10	
Coal	.....	2
Plastic clay, with leaf impressions	2	
"Boulder-flint" clay	3	
Semi-hard clay	3	
Pinkeye clay	3	
Limestone.		

Crider states that lens shaped bodies of sandstone known as "silica boulders" or "nigger heads" were present, and usually at the top of the clay. They consist of minute grains of sharp sand cemented by fire clay.

The Qualls Mine (Ref. 8, p. 618) was also noted by Crider. It averages about 2 feet flint clay and 4 feet No. 2 plastic clay. In places there is 12-18 inches of semi-hard.

Among the interesting features of this deposit are "silica boulders," found in all parts of the clay bed but mostly at the top, and which may contain angular fragments of flint clay. This is similar to the whim rock found over the clay at Hayward. The flint is separated into two grades, of which the No. 1 may show oolites and No. 2 iron sulphide. Leaf impressions are said to occur both in the No. 2 plastic, and in the silica boulders.

The following analyses have been supplied by the Harbison-Walker Refractories Company as illustrating the three types of fire clay found in the Olive Hill district:

	Flint Clay	Semi-hard Fire Clay	Plastic Clay
Silica	45.66	50.52	58.40
Alumina	37.92	34.83	29 77
Ferric oxide	1.82	2.13	2.51
Lime	.30	.55	.25
Magnesia	.56	.74	.55
Alkalies	.88	.90	1.03
Ignition	12.72	10.61	9.35
	99.86	100.28	99.86

The fusion point of carefully selected flint clay is said to be between cones 33 and 34.

The factory of the Harbison-Walker Refractories Company is connected with the mines by a narrow gauge road, and the clay cars are run in on a trestle from which the clay can be dumped into storage bins. From these it passes to dry pans, then through screens to the bins for ground clay. Tempering is performed in wet pans.

Standard brick are molded in a stiff-mud machine and hand repressed, while special shapes are molded by hand.

All of the drying is done on steam-heated floors. There are 16 circular down-draft kilns, and the firing takes 7½ to 9 days. It is said that cone 12 is turned over at the bottom and cone 14 at the top, but the completion of the firing is judged by the appearance of the kiln.

The plant has a daily capacity of 60,000 brick, and the product includes fire brick for blast and open-hearth furnaces, locomotive blocks, stove brick, etc. The brands are Hearth and Bosh, high grade, No. 1 and stove.

General Refractories Company. The mines being operated by this company are located 5 miles north of Olive Hill, in the

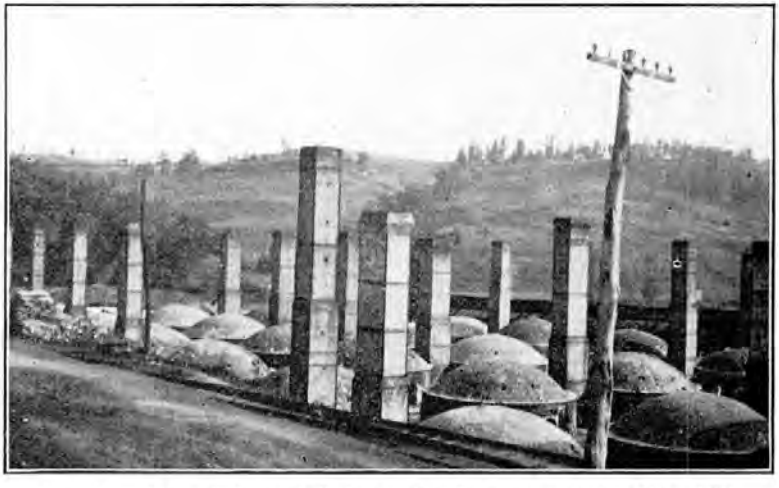


Fig. 51. Kilns at General Refractories Company works, Olive Hill.

ridge between Trough Camp Branch and Smoky Creek. The generalized section is:

Sandstone	.....
Shale or sandstone	.....
No. 2 plastic clay	0-1½ ft.
Flint clay	0-4 ft.
Semi-hard clay	1-4 ft.
Pinkeye clay or sandstone	.....
Limestone	.....

The total thickness of the fire clay varies from 4-6 feet, and is mostly flint and semi-hard clay. The No. 2 plastic clay is

sometimes found above the flint clay, while the pinkeye generally forms the floor. The fire clay may occasionally show specks of siderite, pyrite or gypsum.

The flint and semi-hard clays are usually mined together, but occasionally the flint is sandy and then has to be rejected.

The clay is hauled to the plant over a narrow gauge railroad. It is first run through a crusher, and from this to a dry pan and screen. The different clays and ground grog are stored in separate bins. An ingenious automatic mixer is used to combine the clays and grog in proper proportions, and this machine may be adjusted to yield different mixtures. The mixture is tempered with hot water in a double pugmill, and in a single shaft pugmill.

Molding is done in a stiff-mud machine, even some shapes which are commonly molded by hand being formed in this manner.

Most of the bricks are repressed in power driven represses, but a few are handled in hand power ones.

The bricks receive 3 days' drying in a tunnel dryer, but in addition the flat top of the tunnels is sometimes employed for drying. There is also a large steam-heated drying floor. The plant has 27 circular down-draft kilns, and firing requires 9 days. No cones or pyrometers are used. The daily capacity of the works is 90,000 brick. The factory is spaciously laid out and of fireproof construction.

Inactive Mines

Burnt House Mine. This was opened up about 1899 by the Olive Hill Fire Brick Company, but has been worked out.

Greaves-Walker (Ref. 19, p. 467) notes that a remarkable feature of this mine is its natural roof of sandstone from 1 foot to 18 inches thick, which is so strong and hard that rooms 30 feet wide have stood for 4 or 5 years without the use of props. The section given by him is:

1.	Sandstone roof	1-1½ ft.	
2.	Black, highly carbonaceous shale, firing dark buff and fusing cone 31	.....	15 to 30 ft.
3.	No. 2 plastic clay, not always present	1 ft. or less	
4.	Flint clay with oolites, called Aluminite.		
5.	No. 1 flint clay. Light cream color, sandy on outer edge of deposit, and there consists of flint clay matrix with quartz crystals	6 ft. average	
6.	Semi-hard clay. White, buff, red, black, gray, and gray spotted red.		
7.	Sandstone floor. Very uneven.		

Greaves-Walker gives a number of interesting analyses of the different grades or kinds of clay from this mine as follows:

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
Silica	44.52	43.56	43.82	43.04	46.20	57.68	58.34	34.76
Alumina	40.81	42.87	39.67	40.97	39.35	27.95	33.34	48.50
Ferric oxide	1.03	.81	1.09	2.27	.10	1.62	1.02	1.26
Lime	.62	1.30	1.43	.74	.15	.51	.72	.76
Magnesia	.55	.21	.11	.17	.09	.24	.36	.11
Alkalies	.....	.....	.....	.....	.22	.....	.....	.....
Ignition	12.11	9.86	11.96	12.52	14.00	11.52	6.13	14.08
Cone of fusion		34	33	.....	.....	33-34	34-35	36

I, II. Semi-hard clay, gray to black color. III. Semi-hard clay, white color. IV. Semi-hard clay, red color. V. Flint clay. VI and VII. Siliceous flint clay. VIII. Oolite flint clay, called aluminite.

Analysis No. 8 represents a peculiar type of flint clay of abnormally high alumina content, due to the presence of oolites in the clay. Greaves-Walker suggested the name of Aluminite for this clay (Ref. 19). Galpin (Ref. 16) later showed that these oolites consisted of the mineral gibbsite. Crider has noted the occurrence of oolitic flint clay at one or two other localities, and the writer has noticed small amounts of it in the plastic fire clay at Hitchins.

Greaves-Walker calls attention to the fact that in the School House mine, just across the ravine from the Burnt House mine, none of the Aluminite clay was found, showing that it is evidently of very local occurrence.

Another locality for oolitic flint clay mentioned by Crider (Ref. 8, p. 630) is on Frank Rivers' land, near the head waters

of Sugar Camp Branch, and within a few hundred yards of the Lewis County line.

Olive Hill Calcine Company mine (Ref. 8, p. 631). This is no longer in operation, but was located on the right fork of Henderson's branch, 1 mile from Olive Hill. (No. 36, Fig. 42). The section given by Crider is:

	Ft.	In.
Sandstone and shale	.....	
Hard shale, leaf impressions	20	
Coal	.....	2
No. 2 flint clay, with leaf impressions	1½	
Plastic clay, with leaf impressions	1½	
Flint clay	2½	
Semi-hard clay	2½	
Limestone.		

Here it is interesting to note that there is neither pinkeye clay nor sandstone between the fire clay and limestone. The "silica boulders" may come in from the top and cut out the clay, and Crider admits that they may represent the filling of erosion channels. However changes in the thickness of the clay are said to be due more often to inequalities of the floor than of the roof.

ENTERPRISE

Ironton Fire Brick Company. The company has a plant at Ironton, Ohio, and until recently had been operating almost exclusively on Ohio clay, but in the future intends to use nothing but clay from its Kentucky holdings. The firm has recently opened a mine on the south side of the Chesapeake and Ohio Railway about ¼ mile southwest of Enterprise. In August, 1921, the tunnel had been driven about 300 feet. The clay, which is all of the semi-hard type, so far as the tunnel had been driven, is more siliceous on the outcrop, and the section shown is:

	Ft.	In.
Black shale with mud cracks	.....	
Coal, not continuous	.....	2
Semi-hard fire clay	4	
Mass of tightly packed chert, with ferruginous clay in the openings	1½-2	
Limestone	3	
Covered	20	
Sandstone	.....	

The limestone is evidently not very thick at this point.

The following analysis of the fire clay has been supplied by the Ironton Fire Brick Company:

Silica	44.84
Alumina	38.89
Ferric oxide	1.35
Lime	.52
Magnesia	.40
Alkalies	.53
Ignition	13.72
	100.25
Cone of fusion	33

Chas. Taylor and Sons Mine. This firm has a fire brick plant at McCall on the Ohio River in Greenup County, and another one at Cincinnati, Ohio. Their mine is located ¾ mile southwest of Enterprise on the south side of the Chesapeake and Ohio Railway.

The order of succession of the different materials in the mine, as given by the mine foreman is:

Slaty shale.
Whim rock (sandstone).
Coal.
Sand rock.
Semi-hard clay with little flint.
Pinkeye.
Green or yellow ocher.

In drilling over 6,000 acres of ground they found the pinkeye reaching a maximum thickness of 18 feet, but in places it was replaced by sandstone, which occasionally also took the place of the fire clay as well. In some bore holes the flint clay was found to rest directly on the limestone. The "huckleberry" clay may be almost directly over the fire clay or 50 feet above it.

Hayward. Ashland Fire Brick Company. This company has fire clay mines and also a refractories plant located at Hayward, both being on the south side of the Chesapeake and Ohio Railway tracks. The company has about 2,700 acres of clay land. There are two mine openings in the hills east of the

works, the two being known as the Gartrell and Hayward. The workings are connected.

The general section in the mine is:		Ft.	In.
Shale		.....	
Sandstone (Whim rock)		.....	18
Coal		.....	1-2
Flint clay. Average		3	
Maximum 11 ft.	Semi-hard clay	4	
	(S, No. 2 plastic occasionally with semi-hard.)		
	Sandstone or pinkeye clay.		

The following comments are to be made on this section. The whim rock is a hard sandstone, which is rarely over 18 inches thick and rests directly on the fire clay, except where a

Fig. 52. Looking towards entrance of fire clay mine of Ashland Fire Brick Company at Hayward.

layer of coal 1-2 inches thick lies between. It sometimes shows small angular inclusions of what appear to be fire clay. In places the whim rock dips, and the fire clay appears to grade into it.

Below the whim rock, there may be flint clay, semi-hard clay or No. 2 plastic, or in other words the three grades of clay show no regularity of arrangement. Most of the clay is of the semi-hard type, and there is very little of the plastic.

The flint clay ranges from light to dark in color, and occasionally shows red tints. It is sandy in places, and in the Hayward mine grades into a soft sandstone towards the entrance.

The semi-hard is mostly above the flint in one mine, and mostly below it in the other. It shows the usual slickensides, and these dip usually east or west, both sets not being found in the same part of the deposit.

The shale overlying the whim rock contains abundant *Stigmaria*, some of these being as much as 10 feet long.

Gypsum in thin films is occasionally found in the joints of the fire clay, and there are also sometimes found small white specks of undetermined character. The floor of the mine may be either pinkeye or sandstone.

Crider has also referred to this mine and notes the occurrence of shale, which partly underlies the clay. The sketch which he gives resembles an unconformable relation between the two.

The clay from the mines is in part shipped to Ashland for use at the works of the company at that place, and in part used at Hayward.

The Hayward plant has a daily capacity of 25,000 brick, and produces both standard fire brick and special shapes. They are all made of a mixture of semi-hard and flint clays, which are stored in piles before use.

The clay is ground in a dry pan and tempered in a wet pan or pugmill. The standard shapes are molded in a stiff-mud machine and the special shapes by hand. All drying is done on hot floors. Firing is done in down-draft kilns.

Soldier

J. D. Patton Mine. This is located just west of Soldier and northwest of the Harbison-Walker Refractories Company's Mine. It was idle at the time of our visit. The general section in the mine is:

	Ft.	In.
Sandstone (asphaltic)	.....	
Shale	.....	
Coal, not continuous	.....	0-2
No. 2 plastic clay	.....	0-12
Flint clay	1½	
Semi-hard clay	2-4	
Sandstone or pinkeye.		

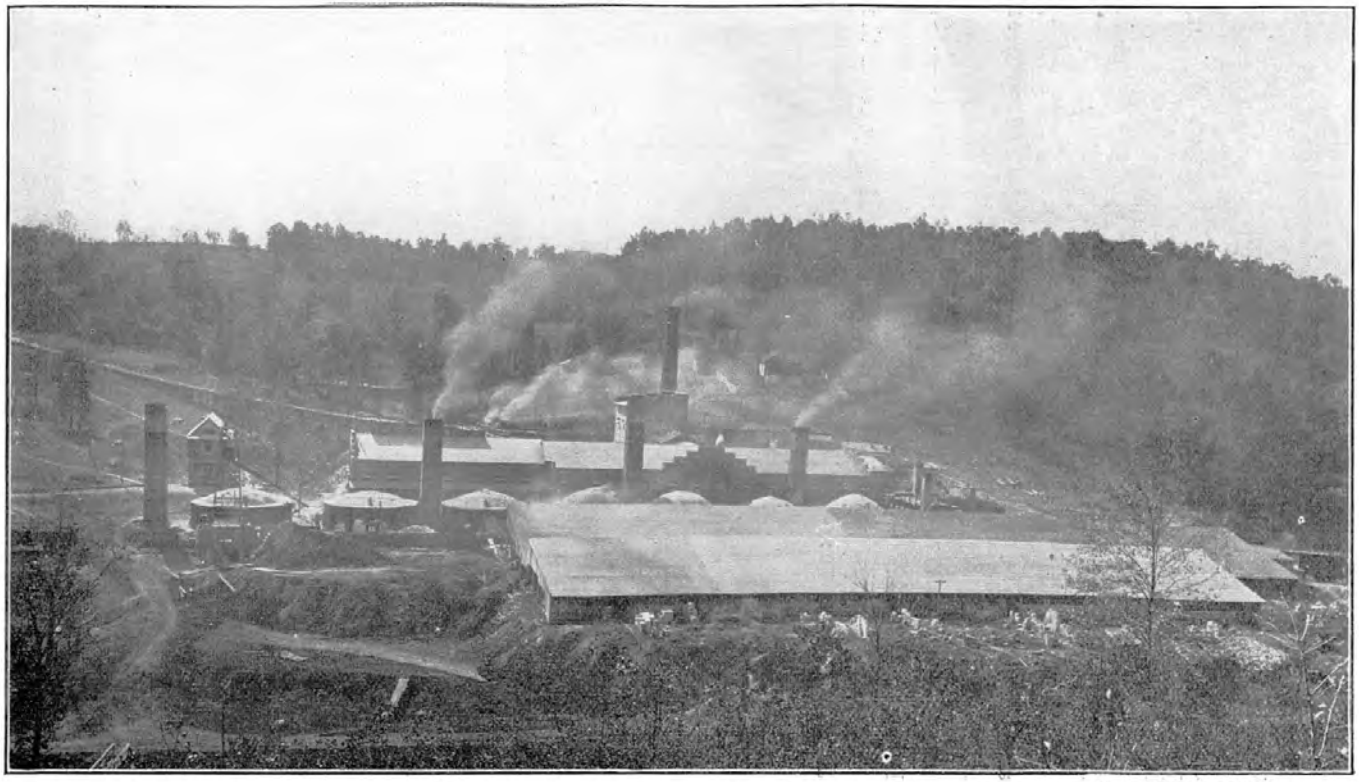


Fig. 53. Ashland Fire Brick Company, Hayward.

PHOTO BY W. R. JILLSON

The shale roof shows asphalt seepages, the material from these having soaked down into the cracks of the clay.

As can be seen from the section there is very little of the No. 2 plastic clay, and in places it is absent. It varies from light colored portions to others which are almost black.

The flint clay averages 18 inches or less and sometimes is very sandy.

The semi-hard fire clay is the chief kind found in the mine, and runs usually from 3 to 4 feet thick. Its fracture surfaces may be coated with thin crusts of gypsum.

Crider also makes reference to the Patton mine (Ref. 8, p. 638) in his report.

The following analysis by C. E. Bales, is of clay from the J. D. Patton mine:

Silica	56.20
Alumina	31.22
Ferric oxide	1.80
Lime	.14
Magnesia	.13
Alkalies	.46
Ignition	10.06
	100.01

This clay has been used in the manufacture of fire brick.

Harbison-Walker Refractories Company Mine. This is located just south of Soldier and on the south side of the Chesapeake and Ohio Railway tracks.

The fire clay averages 3½-5 feet in thickness, and about one-third of this is flint clay. There is little No. 2 plastic clay. Neither the flint clay nor the semi-hard clay occupy any definite position in the fire clay deposit.

The roof is shale with a thin layer of coal under it at times, while the floor is pinkeye or sandstone.

In mining the clay, the semi-hard and flint clays are mixed.

The following analysis of No. 2 plastic clay, from the Harbison-Walker mine has been supplied by Mr. C. E. Bales:

Silica	48.52
Alumina	36.04
Ferric oxide	1.98
Lime	tr.
Magnesia	None
Alkalies	.40
Ignition	13.10
	100.10

P. Bannon Pipe Company. This firm has about 300 acres of clay holdings in the vicinity of Soldier. A mine has been opened up ½ mile north of Soldier, and a tunnel driven about 180 feet. The roof is said to be sandstone, and the fire clay about 5 feet thick. It consists of flint and semi-hard.

The mine is not being operated at present.

Ashland Fire Brick Company, Clinton Mine. This mine was formerly operated by the Clinton Fire Brick Company, and for a time after the Ashland Fire Brick Company absorbed the former corporation they also continued to work it. It has not, however, been worked for several years, as it is more convenient to get the clays at Hayward. The fire clay was from 5 to 6½ feet thick, and ran about 25% flint and 25% plastic. It had a shale roof and sandstone floor.

Richards Clay Mining Company. This company is preparing to ship clay from a mine located ¾ mile northeast of Soldier.

Miscellaneous Localities. Crider (Ref. 8) notes several other openings around Soldier, one of these being 2½ miles north of this locality.

One occurrence noted by him is on the J. Pence land 1 mile east of Carter, and on a branch of Buffalo Fork. The section recorded is:

Conglomerate	.....
Covered	8 ft.
Oolitic flint clay	4 ft.
Impure sandy flint clay	1½ ft.
Pinkeye.	

Crider claims that at the extreme north end of a hill facing Buffalo Fork, the fire clay was found at two horizons, one at

the base of the conglomerate, and another 20 feet above its base. As we have not seen this section we are unable to verify it.

Non-refractory Clays. The new Midland Trail between Olive Hill and Grayson has a number of cuts along it in which Pennsylvanian shales are exposed, and which are worthy of more detailed investigation than we were able to give them in this reconnaissance work.

One of these cuts is along the road about 3 miles southwest of Gregoryville. Here the section shows about 15 feet of soft gray clay shale, with limonite mottlings, and occasional concretions of limonite. The full extent of the deposit can only be determined by boring or test pitting, but a sample was collected by trenching down the face of the bank from top to bottom.

The following data represents the results of some tests made on this material (Lab. No. 2448):

Lime carbonate	None
Working quality	Excellent
Plasticity	Excellent
Slaking time	30 minutes
Air shrinkage (linear)	5%
Color after firing	Buff
Steel hard	950° C.

	Fire Shrinkage	Absorption
	%	%
950° C.	2.5	8.0
1050° C.	6.0	8 0
1070° C.	7.0	1.5
1130° C.	8.5	0.2
1250° C.	7.5	0.6

This is an excellent buff-burning clay which should make a good face brick. It may possibly prove useful in paving brick and sewer pipe.

Elliott County

This county is undeveloped so far as its clay resources are concerned, due partly to the fact that there are no steam lines of transportation entering the county, and partly because fire clays can still be obtained from more easily accessible localities.

It seems probable, however, that there may be considerable reserves in this county, some of these being held by large companies.

Deposits of fire clay which in some cases are over 20 feet thick have been reported.

Crider (Ref. 8, p. 641) reports fire clay outcropping in the town of Elliottsville a short distance below the postoffice. It is also said to show on the Jesse Bryant place near the head of Andy White branch, where it is 30 feet above the limestone with sandstone between, while farther down the same branch the clay rests directly on the limestone.

Again on the Walker branch 2 miles below Elliottsville, the flint-clay shows 7 feet thickness.

Greenup County

Greenup County lies in the northeastern corner of the state. Most of the county is underlain by Pennsylvanian rocks, but the Mississippian is exposed along Tygarts Creek and its branches. Along the Ohio River there is a narrow strip of river-terrace deposits which might yield pockets of alluvial clay.

The flint fire clay and its associates have been pretty well tested out by drilling in this county, especially in the Tygarts Creek drainage area, but all of the clay found at the fire clay horizon is not of refractory quality nor is the Mississippian limestone always present. In fact, from Coal Branch, 1 mile north of Greenup, up to Tongs, it is absent. North of Tongs it forms thin bands around the hills around the point between the Ohio River and Tygarts Creek. At Limeville a bed of greenish refractory shale is found over the limestone, and at the flint clay horizon. It is only where the Mississippian rocks are exposed that the flint and associated fire clays will be found outcropping.

In the extreme eastern part of the county, near Russell, the plastic fire clay horizon of the Vanport limestone is accessible.

At the present time no fire clay mines are being operated in Greenup County. Some years ago the Chas. Taylor and Sons Company, of Cincinnati, operated a fire clay mine on the south side of Schultz Creek, 6 miles south of McCall, where the firm

has a fire brick plant. The section given by Crider (Ref. 8, p. 659) is:

	Ft.	In.
Coarse grained sandstone	100	
Shale	8	
Coal		2-6
No. 2 plastic dark blue clay	3	
No. 1 flint clay	5	
Pinkeye.		

The clay is inferior to that mined in the Olive Hill district and the company is now obtaining its supply from its mine near Enterprise, Carter County.

The two following analyses are given by Gardner (Ref. 13, p. 204) of fire clays from the Tygart Fire Brick Company at Fullerton. These are supposedly from the mines on Schultz Creek. I is No. 1 flint clay and II is No. 2 fire clay.

	I.	II.
Silica	42.52	67.52
Alumina	35.81	19.93
Ferric oxide	3.24	1.26
Lime	.34	.29
Magnesia	.12	.14
Potash	.20	1.41
Soda	.20	.22
Titanic oxide	2.00	1.60
Sulphur trioxide	.09	.12
Ignition	14.13	6.58
Moisture	.51	.68
	99.16	99.77

Chas. Taylor and Sons Company, successors to the Tygart Firebrick Company, have a fire-brick plant located at McCall postoffice, opposite Portsmouth. The product consists of fire brick and special shapes and the plant has a daily capacity of 40,000 brick. The raw material used is obtained chiefly from the company's mine at Enterprise. The clay is tempered in wet pans, and the bricks are molded in a stiff-mud machine and repressed in hand-power presses. Drying is all done on heated floors, and firing in down-draft kilns, of which there are 6 round and 3 square ones. Cone 9-10 is bent over in the bottom of the kiln.

The brands are Tiger Steel, Tiger Crown and Tiger. The company also manufactures a brick of special refractoriness which bears the trade mark of Tayco, and which is made of different clay from the other brands.

The following data on the Tiger Steel brand of brick made by Raymond M. Howe of the Mellon Institute, have been supplied by Mr. Taylor:

Silica	59.46
Alumina	36 07
Ferric oxide	2.72
Lime	.68
Magnesia	.48
Alkalies	.41
Ignition	.00
	99.82
Cone of fusion	32

Knox County

Little is known regarding the clay resources of this county. Crandall and Sullivan (Ref. 5) in their report on the coalfield around Pineville Gap, give a number of sections showing clay under the coals, but no mention is made of its character.

The only clay being worked in this county is at Barboursville, where the Barboursville Brick Company is manufacturing common brick from a deposit of alluvial clay which is 6-14 feet thick and underlain by sand.

The clay is ground up in disintegrators, tempered in a pug-mill, and molded in a stiff-mud, end-cut machine. The bricks are dried by artificial heat, and fired in circular down-draft kilns.

The plant is located at the junction of the Louisville and Nashville and C. and M. Railways.

Lawrence County

An interesting shale has been sent to the Geological Survey by Mr. C. E. Stafford of Huntington, W. Va., who states that the material is found overlying the Peach Orchard coal seam at Torchlight, Kentucky.

The material is a dark gray shale, said to be from 2-5 feet thick, with the coal as a floor, and sandstone as a roof. It would not be practicable to work it alone, but it is claimed that the shale could be easily worked in connection with the coal, which is 4 feet thick.

The following tests of the shale (Lab. No. 2472) were made on a sample supplied by Mr. Stafford:

Plasticity	Fair
Slaking time	12 minutes
Air shrinkage (linear)	3%
Steel hard, not ove·	1250° C.

Firing tests.

Temp.	Fire Shrink.	Absorption	Porosity	Color
	%	%	%	
950° C.	1.5	8.2	25.4	Buff
1050° C.	2.0	6.7	21.2	Buff
1150° C.	2.0	5.5		Buff
1250° C.	2.0	4.5		Buff
1310° C.	4.0	1.3	7.8	Gray buff
1430° C.	Overfired.			

This is a good material which burns to a good product and a splendid buff color. It should be of use in the manufacture of face brick, and could probably be used in a flue lining or sewer pipe mixture. It is not a fire clay as it is overfired at 1430° C. While the plasticity is not high, it is sufficient to permit its being molded in a stff-mud machine.

Lee County

Most of this county is underlain by Pennsylvanian formations, but along the Kentucky River between Evelyn and Beattyville the Mississippian shales are exposed and might supply brick material.

At the mine of the Beattyville Coal Company, 2 miles west of Beattyville, the coal has a hard shale roof and a hard sandy shale floor.

At the mine of the Kentucky River Coal Company, 1½ miles east of Beattyville, a similar hard shale overlies the coal, while the floor is of sandstone.

No tests of the shale were made in either case.

Letcher County

This county is all underlain by Pennsylvanian rocks except a narrow strip of Mississippian along the Pine Mountain thrust fault. If the Mississippian is of any value the best place to work it would be in the vicinity of Jenkins as it is near the railroad.

At McRoberts in mine 213 of the Consolidation Coal Company, the Elkhorn Coal has a roof of blue slaty shale, and a clay parting about 3½ feet below the roof. This parting which varies from 1 to 40 inches in thickness, with an average of 18 inches, is hard, black, free from grit, but slakes easily. The material (Lab. No. 2460) is to be classed as a lean non-calcareous shale, which fires to a red, fairly hard body, and is not refractory. The material below the coal is like that forming the parting.

At mines 214 and 215 of the same company, located ¼ mile east of McRoberts on the Louisville and Nashville railroad, the same clay parting is found, but it is only from 1 to 6 inches thick.

At Jenkins, the Elkhorn coal in the mine of the Consolidation Coal Company, shows the same parting as at McRoberts, but here it runs about 16 inches thick.

Lewis County

Clay-bearing Formations. This county lies entirely without the Pennsylvanian area. The larger part of it is underlain by Mississippian formations.

Thus the Waverly formations occur in the hills along the valley walls, and form the surface formations in most of the county, with the exception of a narrow belt along the western border of the county, one extending up the Ohio Valley and one up the deep valley of Salt Lick.

The shale formations found in the county are the Estill, Ohio, Bedford, Sunbury and New Providence.

The Estill is to be looked for only in the western part of the county. Easton (Ref. 10, p. 861) gives some partial tests of a sample from "Carr's Fork of River Road," which he states is very plastic, with 5% air shrinkage, 5% fire shrinkage, and vitrifying at cone 1. It burns to a dark red color.

The Ohio and Sunbury shales on account of their carbonaceous and gritty character when fresh are of no value.

The Bedford shale is rarely present in large quantities, and is not to be regarded as the best type of shale for making clay products. A sample (Lab. No. 2446) was collected from a point 2 miles south of Vanceburg, not because the deposit is commercially important, but more because it afforded a good place to collect a sample. It can be described as a gritty, non-calcareous shale, which has enough plasticity when ground and mixed with water to permit its being used for making brick. It fires to a rather porous, but moderately hard red brick at 950°C., but is inferior to the New Providence, Lulbegrud or Estill shales.

The New Providence shale is by far the most important one in Lewis County, and is worked at Fire Brick on the Ohio River, a short distance southwest of Portsmouth, Ohio.

Firebrick. At this locality the New Providence shale is utilized by the Peebles Paving Brick Company for making paving blocks. The plant has been operated by the present company since 1914, and before that was known as the Portsmouth Granite Brick Company. Still earlier firebrick was made here, the fire clay being obtained from the Pennsylvanian formation which caps the ridges to the south of the plant.

Fig. 54. Shale bank of Peebles Paving Brick Company at Firebrick.

The New Providence shale utilized at the paving-block works is exposed in a high bank to the east of the factory. The material is blasted down, and a little residual clay from the shale gets mixed with the latter. The following tests indicate the character of the shale (Lab. No. 2449):

Lime carbonate	None
Working qualities	Good
Plasticity	Good
Water of plasticity	18.6%
Slaking time, minutes	26
Modulus of rupture, lbs. per sq. in.	80.8
Air shrinkage (linear)	3%
Color after firing	Red
Steel hard	950° C.

	Fire Shrinkage	Absorption
	%	%
950° C.	1.	10.7
1050° C.	3.	3.0
1090° C.	3 5	2.4
1150° C.	6.5	1.4
1190 C.	Nearly overfired	

Fig. 55. Peebles Paving Brick Co., Firebrick.

This clay is used for paving block, but it could also be used for hollow blocks, drain tile and common brick.

It is similar to the shale from the same formation at Junction City and Coral Ridge.

The shale after quarrying is trammed to the works where it is ground first in a dry pan and then screened. Tempering

Fig. 56. Kilns of Peebles Paving Brick Company.

is done in a pugmill and molding in a stiff-mud side-cut machine, using a Dunn device for making an undulating cut through the clay bar. At the same time the name of brick is stamped on the clay bar.

Drying is done in tunnels heated by waste heat from the kilns. The tunnels are 140 feet long and the drying takes 48 hours.

There are 6 circular down-draft kilns, which are part of the original plant built here by the Harbison-Walker Refractories Company. In addition the present company has built 4 rectangular down-draft kilns.

The clay shows some tendency to scum, but it makes a good hard block. According to figures supplied by the company the paving blocks show a loss of from 17 to 20 per cent on the abrasion test.

Perry County

There are several coal mines in this county, which have shale associated with the coal, but none of them were tested. The following may be noted:

Typo. Liberty Coal Company, 2 miles east of Typo or First Creek branch of Louisville and Nashville Railway. The No. 6 coal, which is being worked, is overlain by 2 feet of soft gray, slightly gritty clay, full of leaf impressions. This is evidently softened by weathering, as farther in the mine it becomes very hard. The floor of the coal is composed of a 3-foot layer of very hard slaty shale.

Hazard. In the mine of the Bluegrass Coal Corporation the No. 6 coal has a shale roof, but it contains several thin coal streaks. The floor is a hard shale of very low plasticity.

In another mine of the same company, ¼ mile south of Hazard, the No. 4 coal shows a roof of hard shale and sandstone, while below the coal is 18 inches of soft, gray, slightly gritty clay, containing many fern impressions. The No. 7 coal worked by the same company shows similar materials in the roof and floor.

The Perry Ice and Coal Company is also working the No. 4 coal, and the roof and floor materials are like those in the other mine.

Pike County

Most portions of this county lie rather remote from the railway. Samples were obtained from the mine of the T. N. Hoffman Coal Company, on the east side of the Big Sandy River at Pikeville. The roof material is a slaty shale, and the floor is of similar character. Neither materials are refractory.

Rowan County

Clay-bearing Formations. Rowan County contains formations ranging from the Silurian to Pennsylvanian inclusive.

Silurian beds occupy but a small area in the most western part of the county bordering the valley of the Licking River.

Devonian strata occupy a narrow belt in the valley of Triplet Creek eastward to Morehead, in the valley of North Fork at Triplet Creek, and in the Licking River Valley.

Mississippian formations underlie most of the remainder of the county, except for a strip of Pennsylvanian along its eastern border. There are also some outliers of Pennsylvanian rocks.

Of these several formations the only ones that have been worked are the fire clay beds lying on the boundary between the Pennsylvanian and Mississippian.

Fire Clay Deposits. Fire clays were being worked during the summer of 1921 at Haldeman and on Christy Creek, 5 miles southeast of Morehead.

Haldeman. Kentucky Firebrick Company. This company whose main office is in Portsmouth, Ohio, has extensive clay holdings at this locality, while a holding company known as the Kentucky-Pennsylvania Fire Clay Company, associated with the preceding has additional clay lands. Other companies holding clay land in this vicinity are the Gilmore Fire Clay Company and the Harbison-Walker Refractories Company.

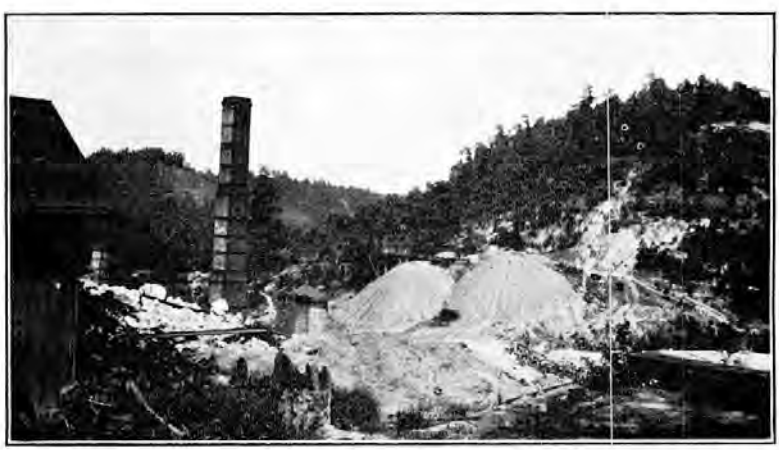


Fig. 57. View from upper mine of Kentucky Fire Clay Company at Haldeman, looking towards dump of old mines.

The only company operating here at present is the Kentucky Firebrick Company which has two fire-brick plants.

The mines worked are located in the hill south of the plants, and the deposit has been opened up by several tunnels and with cross entries connecting them. One tunnel enters the hill above the eastern plant and the other nearer to the western plant.

The deposit contains flint clay, semi-hard clay, and No. 2 plastic clay, but the position of the flint clay with relation to the other two may vary in different parts of the mine. This is shown by the following four sections:

I.

	Ft.	In.
Black shale		5/8-3
Coal	2	
Flint clay	2-3	
Semi-hard clay	3	
No. 2 plastic clay.		

II.

	Ft.
Black shale.	
No. 2 plastic clay	1½
Flint clay	2
Semi-hard clay	2½
Pinkeye.	

III.

	Ft.	In.
Shale		
Coal		1
Semi-hard clay	1½	
Flint clay	2	
No. 2 plastic clay	2	

IV.

	Ft.
Shale	2
Semi-hard clay	2
No. 2 plastic	1½
Pinkeye.	
Sandstone.	

Vegetable matter and thin films of gypsum may be present, especially in the flint clay. The pinkeye which frequently occurs in the floor, fires to a buff brick with minute iron spots.

Crider (Ref. 8, p. 638) also gives a section from this mine, which in a general way resembles those given above except that he notes occasional thin shale layers between the coal and plastic clay, and also gives the coal as 4 inches thick, showing that it is of variable thickness.

The clay is trammed from the mines in small cars to the tipple, where it is passed through a jaw crusher. It then goes to dry pans and screens, after which it is distributed to the bins.

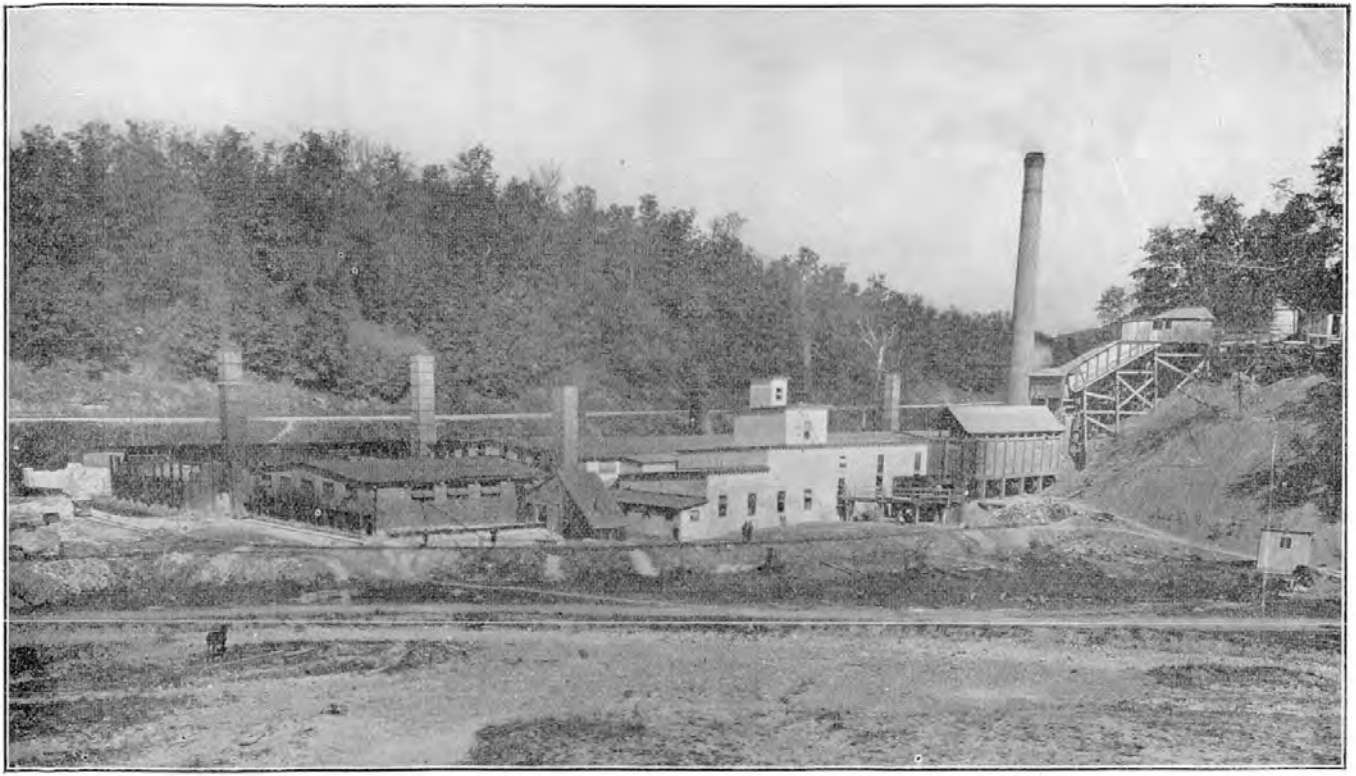


PHOTO BY W. R. JILLSON

Fig. 58. Kentucky Fire Clay Company, Haldeman.

All three grades of clay are used in different proportions, together with grog for making the different grades of brick. The clay for special shapes is tempered in wet pans, and these as is commonly the custom are molded by hand. For standard shapes the clay is tempered in a pugmill and then molded in an auger machine.

The special shapes are dried on floors, while the standard shapes are put through tunnels heated by waste heat from the kilns, and this requires 36 hours.

Burning is done in down-draft kilns of which there are 13 at the No. 1 plant and 11 at the No. 2 plant. The firing requires 9 days, and cone 8 is said to be turned down in the bottom of the kiln.

The two plants have a capacity of 40,000, and 35,000 bricks daily, respectively.

Hays Crossing. Gilmore Fire Clay Company. The head office of this company is at 421 Wood street, Pittsburgh, Pa., and the corporation has over 5,000 acres of land in this region. Most of the fire clay is said to be located on the waters of the East Fork of Triplett Creek, Buffalo Run, Slab Camp Run, Sees Branch, Paddy Lick, and Deep Ford of Christy Creek. The clay is nearly all on the south side of the Chesapeake and Ohio Railway.

The Hays Crossing mine contains mostly No. 2 semi-hard clay, 5 to 8 feet thick, with a shale roof and a floor of pinkeye 3-4 feet in thickness. Below the pinkeye is limestone.

A layer of coal ½ to 12 inches thick runs all through the property, and is usually present as a parting in the semi-hard, 4-5 feet above its base.

The company has flint clay on the Slab Camp Run, Deep Ford Paddy Lick, and Sees Branch of Christy Creek. This clay is said to be 3-4 feet thick, with 2-4 feet of semi-hard coming in on top of it. The flint clay has a sandstone floor and roof.

Mr. C. E. Bales has supplied the following analysis of a No. 2 plastic fire clay from the mine of the Gillmore Fire Clay Company:

Silica	53.86
Alumina	32.40
Ferric oxide	1.52
Lime	.62
Magnesia	.10
Alkalies	.50
Ignition	11.40
	99.98

Morehead. General Refractories Company. This company is operating mines located 5 miles southeast of Morehead, on a spur track from the Chesapeake and Ohio Railway. There are two mines known as Nos. 1 and 2, and the two following sections give the average thickness and character of the material in each:

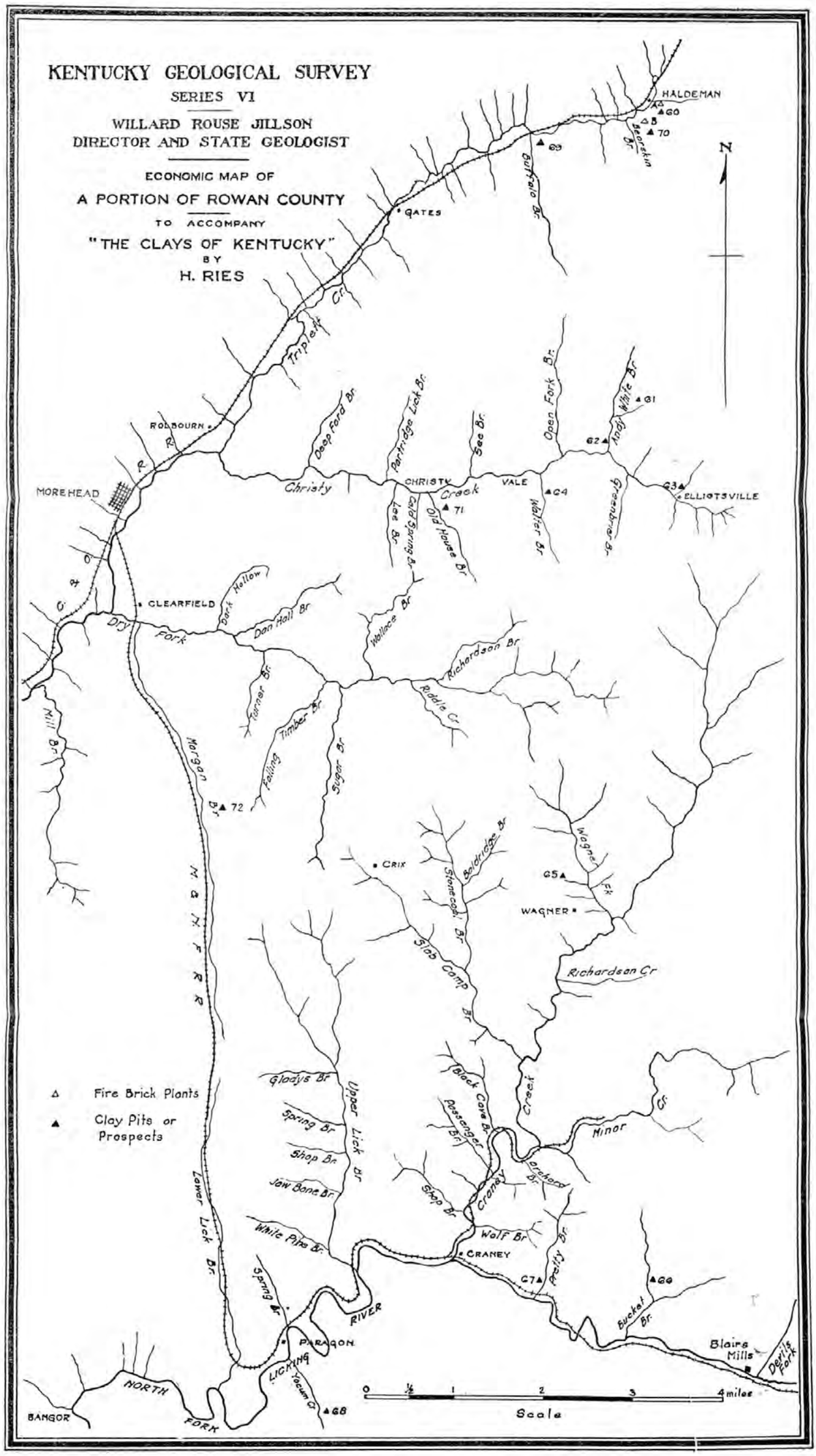
	I.		II.	
	Ft.	In.	Ft.	In.
Black shale roof	.....		.....	
No. 2 plastic clay	1-2		2	
Coal	.....	0-8	.....	0-8
Flint clay	4-5		3½	
Semi-hard clay	1-2		1½	
Sandstone	.....		.....	

Overlying the roof shale is sandstone, but the contact between the two is more or less obscured by weathering products. The No. 2 clay is occasionally as much as 3 feet thick. In the No. 2 mine the No. 2 clay is sometimes found entirely above the coal, in which case the flint clay is usually overlain by a thin layer of coal, and sometimes even grades into the latter. This clay is generally light in color, and may contain small white spots that are possibly gypsum.

The semi-hard clay varies in thickness in both mines, but does not show the white spots above mentioned. It is usually sharply separated from the flint and always lies below it.

Miscellaneous Fire Clay Occurrences. The Clearfield Lumber Company owns large tracts of land in Rowan, Morgan and Elliott counties, and has done some prospecting in the flint clay deposits.

One flint clay deposit shows up on Clark Mountain 3 miles from Morehead: also on Buckett Creek in Morgan County, 17 miles from Morehead. The section here is:


KENTUCKY GEOLOGICAL SURVEY
SERIES VI
WILLARD ROUSE JILLSON
DIRECTOR AND STATE GEOLOGIST
ECONOMIC MAP OF
A PORTION OF ROWAN COUNTY
TO ACCOMPANY
"THE CLAYS OF KENTUCKY"
BY
H. RIES
N
HALDEMAN
GATES
ROLBOURN
MOREHEAD
CLEARFIELD
CHRISTY
VALE
ELLIOTTSVILLE
CRIX
WAGNER
CRANEY
PARAGON
BANGOR
NORTH FORK
LICKING RIVER
Triplett Cr.
Deep Ford Br.
Partridge Lick Br.
Open Fork Br.
Christy Creek
Old House Br.
Wallace Br.
Richardson Br.
Riddle Cr.
Morgan Br.
Falling Timber Br.
Sugar Br.
Mill Br.
Dan Hall Br.
Dry Fork
Slab Camp Br.
Richardson Cr.
Gladys Br.
Spring Br.
Shop Br.
Jaw Bone Br.
White Pine Br.
Lower Lick Br.
Upper Lick Br.
Wolf Br.
Minor Cr.
Buckat Br.
Blairs Mills
Devils Fork
Fire Brick Plants
Clay Pits or Prospects
0 ½ 1 2 3 4 miles
Scale

	Ft.	In.
Pebbly sandstone	.....	
Coal	.....	10
Flint clay	4	
No. 2 flint clay	4	
Limestone	10-14	
Clay	5	
Gray sandstone	.....	

Crider (Ref. 8, p. 643) refers to a fire clay which has been worked on Sam Bradley's land, 3 miles south of Morehead, near the head of Morgan branch. If Crider's diagnosis is correct, the peculiar feature of this clay is that it occurs in the conglomerate, 40 feet above top of Maxville limestone.

Other occurences are noted on the map of a portion of Rowan County, Ky., which is included within this report.

Blairs Mill. A puzzling occurrence of clay is that found on the Morehead and North Fork railroad, south of Morehead, and near the station of Blairs Mill. It has already been noted by Miller, (Ref. 22), because of the possibility of its throwing some light on the age of the flint clays of this region. The exposures near Blairs Mill are as follows:

Along the bank of the creek and in the railroad cut about 200 yards southeast of Blairs Mill the section shows:

Pottsville conglomerate	.....
Covered	20-30 ft.
Sandstone	5 ft.
Gray clay shale	5 ft.
Fossiliferous limestone	4 ft.

The gray clay shale closely resembles the so-called huckleberry clay which is found above the fire clay in many parts of Carter and Rowan counties.

In the railroad cut ¾ mile north of Blairs Mill the section is:

Conglomerate	15 ft.
Gray limestone	6 ft.
Yellow sandy limestone	8 ft.
Fossiliferous shaly limestone	3 ft.
Massive gray limestone	15 ft.
Yellow limestone	1 ft.
"Flint clay"	4 ft.

Limestone.

The conglomerate which shows at the top of the section may possibly not be in place, but higher up the mountain slope are great cliffs of conglomerate. The gray shale resembles the huckleberry seen south of Blairs Mill, but here is interstratified with very thin layers of shaly limestone which are fossiliferous. The so-called flint clay outcrops about the level of the railroad tracks. In its fresh condition it reminds one somewhat of an impure flint clay, has a conchoidal fracture and is quite hard. It is *not refractory*, since at 1430° C. it is pretty well fused.

Again at a point 1½ miles north of Blairs Mill the railroad cut shows the same bed of supposed flint clay, under the yellow limestone, but the clay here is weathered on the outcrop to a somewhat plastic mass of a greenish color. The section at this point is:

Gray limestone	4 ft.
Yellow limestone	9 ft.
"Flint clay," weathered on outcrop	4 ft.
Railroad level.	

It should be said that the limestones referred to in the above sections are all of Mississippian age as determined by their fossils. The fossiliferous shale is classed by Prof. Miller as Pennington shale.

One-half mile south of Blairs Mill a small tunnel has been constructed to carry the water of the North Fork of Licking River. Most of this tunnel is in Pottsville conglomerate, of which at least 40 feet is here exposed, but immediately below the conglomerate there is to be seen 3 feet of a shaly rock which in appearance closely resembles flint clay, and which is probably refractory, for at 1430° C. it shows no signs of being affected by the heat.

The relation of these exposures to the general geology of the flint clays is discussed on an earlier page of this chapter. It is of interest to note in this connection that Crider (Ref. 8, p. 644) gives a section on Yocum Creek, a stream entering the north fork of the Licking River, opposite Paragon, which is as follows:

	Ft.	In.
Conglomerate	.....	
Thin bands of blue limestone	.....	4
Calcareous black shale	5	
Mississippian limestone	.....	

The similarity to the Blairs Mill section lies in the occurrence of the clay rock between the limestones.

New Providence Shales. At Rockville station, a hill lying just west of the quarry of the Kentucky Bluestone Company, is said to show a section of soft, blue, New Providence shales, 90 feet in thickness. The overburden consists of about 15 feet of loose soil, that could be easily stripped off.

Whitley County

Whitley County lies entirely within the area of Pennsylvanian formations. The only development of clay that is known in the county is at Woodbine, where the Corbin Brick Company has a brick plant located ¼ mile south of town. Both common and rough texture brick are made. At the present time only the local market is supplied, but a switch was being put in during the summer of 1921 so that the product can be shipped by rail.

Fig. 59. Clay pit of Corbin Brick Company, Woodbine.

The clay is obtained from a bank located close to the works, and is largely residual from a shale deposit which contains lay-

ers of sandstone. However, a portion of the top may be of alluvial character, having been deposited by the neighboring creek.

The section in the pit is:

	Ft.	In.
Soil (stripped)	.....	8
Yellow clay (burns white)	2	
Dark clay (burns red)	3	
Gray fissile shale	1-4	
Sandy clay (not used)	1-4	

The clay is dug down to the shale floor of the pit. It is hauled up an incline to the works and dumped into rolls. From these it is carried by a conveyor to the pugmill and then to the stiff-mud machine. The clay is sufficiently moist in its natural condition so that no water has to be added to it. Drying is done in tunnels, which are heated by brick flues leading from fire boxes at one end of the tunnel. It requires about 36 hours. The burning is done in 4 circular down-draft kilns, 30 feet in diameter, and requires about 9 days. No cones or pyrometer are used.

The brick vary somewhat in their color according to the clay used. The upper clay is white burning while that in the lower part of the pit burns red. Below the shale seen in bottom of pit is a bed of sandy clay, which is said to burn white, but this is not used.

Gardner (Ref. 13, p. 223) gives the following two partial analyses of clay from Whitley County, without any further data concerning them:

	I.	II.
Silica	59.10	84.76
Alumina	29.76	11.40
Ferric oxide	tr.	tr.
Lime	tr.	tr.
Magnesia	.72	.65
Potash	3.66	1.58
Soda	tr.	.05

I. Is said to be a 5-foot bed on Indian Creek.

II. "Jellico clay" from near the Tennessee boundary.

Wolfe County

This county is underlain entirely by Pennsylvanian formations, except some small strips of Mississippian formations in the western part. There may also be small alluvial deposits along some of the streams.

Several occurrences have been noted by Easton (Ref. 10) and Gardner, (Ref. 13).

Hazel Green. On the O. W. McNabb place 1 mile northwest of Hazel Green, there is a light plastic clay which is said to belong in the coal measures. No data are given regarding its thickness, or the amount of overburden. Easton states that it fires to a pink color, burning to green at cone 9. It has 5% air shrinkage, 5% fire shrinkage, and 29.5 pounds per square inch tensile strength. The clay is vitrified at cone 8.

On the J. B. Kash and J. W. Stamper farms, near the summit of the hills, there is a deposit which Gardner calls flint clay, and which he states is of workable thickness. The material is almost devoid of plasticity and burns white. It has 0% air shrinkage, 6% fire shrinkage and very low tensile strength. At cone 11 the body is granular and porous.

On the S. W. Perkins place, 1½ miles west of Hazel Green, along the Hazel Green and Mt. Sterling road, there is a deposit of alluvial or flood plain clay on the east side of the Red River. It is bluish, plastic, and runs about 6 feet in thickness, with an extent of 30 acres. The material is capped by soil, and rests on shale. It has 5% air shrinkage, 3% fire shrinkage, 52.5 pounds per square inch tensile strength. It is not vitrified at cone 9.

On the farm of W. C. Coldiron there occurs a very smooth plastic clay. Nothing definite is known regarding its extent. A sample sent to the Geological Survey fired to a light red color and was steel hard at 950°C. It is not a fire clay, but could probably be used for brick and tile.

Torrent. On the J. Taylor Day place, ¼ mile west of Torrent, according to Gardner, there occurs a gray clay said to belong to the Pennington formation. It is of low plasticity, has 7% air shrinkage, 0% fire shrinkage, and is incipiently fused at cone 7. The clay burns to a red color.

Glen Cairn. Gardner notes a clay on the N. Fulks place east of town. It outcrops on the side of a hill above the first cut of the Lexington and Eastern Railway. The section as given by him does not indicate workable conditions at this particular locality. It is:

St. Louis limestone	40 ft.
Refractory clay	1½ ft.
Covered	20 ft.
Drab clay	2 ft.
Waverly shale	23 ft.

The shale is rather low in plasticity, fires to a red color and is vitrified at cone 5.

CHAPTER VII.

The Clay Working Industry of Kentucky

Reference to the different clay-working plants has been made under the individual county descriptions on the earlier pages of this report, but it may seem advisable to give here a collective statement regarding the different branches of the clay-working industry as now developed.

The products at present manufactured in the state include common, rough textured, pressed and paving brick, hollow blocks, flue linings, floor, wall and roofing tile, sewer pipe, drain tile, chimney tops, fire brick and other refractory shapes, red earthenware, stoneware, and art pottery. In the majority of cases the different plants obtain their clays close to the factory, only a few of them purchasing clays from outside of the state.

In addition to the manufacturing branch of the clay industry there are a number of individuals or firms engaged in the mining of clay, the product of whose pits is disposed of to a large extent outside of the state.

The different kinds of product will be taken up separately.

Common Brick

These are manufactured at a number of localities, many of the plants having a thoroughly modern equipment. The raw materials used are all of red-burning character and include alluvial clays often underlying river terraces, residual clays and shales. The bricks are nearly always machine made, usually either the soft-mud or stiff-mud process being used, but a few employing the dry-press method of molding. Important localities of production are Paducah, Louisville, and vicinity, Maysville, Madisonville, Firebrick, Henderson, etc. There is an abundance of both clay and shales for common-brick manufacture in many parts of the state.

The following firms are engaged in the manufacture of common brick:

County	Town	Firm Name
Barren	Glasgow	Dickinson Brick and Tile Company.
Bath	Salt Lick	W. M. Harrick Brick and Tile Co.
Boyd	Ashland	J. J. Gates and Company.
Boyd	Bellefonte	Means and Russell Iron Co.
Campbell	Mentor	Busse Brick Co.
Christian	Hopkinsville	Dalton Bros. Brick Co.
Clinton	Albany	R. L. Sloan.
Daviess	Maceo	Maceo Brick and Tile Works.
Daviess	Owensboro	S. B. McCullough.
Daviess	Moseleyville	Clark Manufacturing Co.
Fayette	Lexington	Lexington Brick Co.
Graves	Mayfield	Standard Brick Co.
Hardin	West Point	West Point Brick Co.
Henderson	Henderson	Kleymeyer and Klutey Brick and Tile Works.
Hickman	Clinton	J. A. Harpole.
Hickman	Columbus	Thos. Boodman.
Hopkins	Ashbyburg	Clark Manufacturing Co.
Hopkins	Madisonville	W. L. Hall.
Jefferson	Coral Ridge	Coral Ridge Clay Products Co.
Jefferson	Whitner	Southern Brick and Tile Co.
Jefferson	Louisville	Progress Brick Co.
Jefferson	Louisville	P. Bannon Pipe Co.
Jessamine	Nicholasville	A. H. Schneider.
Kenton	Covington	Busse Brick Co.
Kenton	Covington	Broering & Merer.
Knox	Barboursville	Barboursville Brick Co.
Lewis	Firebrick	Peebles Paving Brick Co.
McCracken	Paducah	Hill and Karnes Brick Co.
McCracken	Paducah	Paducah Brick & Tile Co.
Madison	Bybee	Walter Cornelison.
Madison	Waco	Gristead and Stone.
Marion	Lebanon	Goodwin Brick and Tile Co.
Mason	Maysville	Maysville Brick Co.
Mason	Maysville	Spahr Brick Co.
Muhlenberg	Central City	Central City Brick Co.
Nelson	New Haven	Nelson Brick & Tile Co.
Powell	Stanton	Atkinson and Baker.
Taylor	Campbellsville	Russell Creek Association.
Union	Sturgis	Quinwin Brick and Tile Co.
Webster	Providence	Providence Brick Co.
Webster	Sebree	U. S. Bishop and Sons.
Whitley	Woodbine	Corbin Brick Co.

Rough Texture Brick

A few firms engaged in the manufacture of common stiff-mud brick also produce rough texture brick; a rough-surface brick used for facing walls, and much admired by many people. These include the following:

County	Town	Firm Name
Hardin	West Point	West Point Brick Co.
Lewis	Firebrick	Peebles Paving Brick Co.
Mason	Maysville	Spahr Brick Co.
Whitley	Woodbine	Corbin Brick Co.

Face Brick

Red face brick, of different shades, and sometimes flashed are produced by some of the manufacturers of comomn brick. In many instances they are simply selected common brick that are used for fronts.

Paving Brick

The only firm engaged in the manufacture of paving brick is the Peebles Brick Company of Firebrick, Lewis County. The product is paving block made from the New Providence shale, a formation that encircles the Bluegrass region from Lewis County to Jefferson County.

Hollow Block

There is an abundance of shale in Kentucky which can be used in the manufacture of hollow block, such as the New Providence, Estill and Lulbegrud shale. Some of the coal measures shales like those around Madisonville would also serve well. Even alluvial and other clays are sometimes employed. The product in every case is of red color, and bears an excellent reputation. The following firms are engaged in the production of this class of ware:

County	Town	Firm Name
Daviess	Moseleyville	Clark Manufacturing Co.
Hopkins	Madisonville	Hall Tile Works.
Jefferson	Coral Ridge	Coral Ridge Clay Products Co.
Jefferson	Louisville	P. Bannon Pipe Co.
Union	Sturgis	Quinwin Brick and Tile Co.
Webster	Ashbyburg	Clark Manufacturing Co.
Webster	Sebree	U. S. Bishop and Sons.

It is interesting to note that no hollow blocks are made in the eastern central part of the state, although the New Providence shale occurs there in large quantity.

Flue Linings

These are commonly made from low-grade, buff-burning fire clays or shales. They are at present regularly manufactured only by the P. Bannon Pipe Company of Louisville, and the Owensboro Sewer Pipe Company at Owensboro. The former uses Indiana clay in part, the latter only Kentucky clay. With suitable demand this branch of the industry could be increased.

Floor Tile

Only one factory, the Cambridge Tile Manufacturing Company, of Covington, is engaged in the manufacture of white vitrified floor tile, and similar ones of blue, green and other colors. The product is of the type known as ceramics, and is widely used. The clays employed are obtained from other states.

Red quarry tile of excellent quality are made at Cloverport by the Murray Roofing Tile Company, the raw material being obtained from the Buffalo Wallow shale formation.

Wall Tile

White and colored wall tile, with dull or bright glaze finish or with smooth or embossed surface are manufactured by the Cambridge Tile Manufacturing Company of Covington, and the Alhambra Art Tile Company, of Newport. The raw materials are obtained largely from other states.

Roofing Tile

Only one factory in Kentucky, the Murray Roofing Tile Company of Cloverport, is producing this type of work. The product consists entirely of red shingle tile of fine color and excellent quality. The factory was originally established for manufacturing paving brick. In former years some roofing tile were manufactured from the Irvine clays in Madison County.

Sewer Pipe

As clays suitable for making sewer pipe are not as abundant as other types, factories producing this class of goods are rather restricted. Indeed there are only two sewer-pipe plants in the state. These are the P. Bannon Pipe Company, of Louisville, which utilizes a mixture of Indiana fire clay, semi-hard clay from Carter County, and some New Providence shale. The other is the Owensboro Sewer Pipe Company, of Owensboro, which makes use of low-grade refractory shale from Hancock County.

The practice at both plants is rather unique because of the low temperature at which they salt glaze their ware.

Drain Tile

In point of numbers, the plants engaged in making drain tile in Kentucky, stand next to those producing common brick. They are in some cases the sole product of the plant, while at others they are made in conjunction with brick. While the clays employed must be smoother and more plastic than is necessary for common brick, still at many plants the same material is sometimes used for both.

Alluvial clay, residual clays, and shales are all used at one locality or another. The clays employed are all red burning.

The firms engaged in making drain tile are given below:

County	Town	Firm Name
Bath	Salt Lick	W. M. Karrick Brick & Tile Co.
Christian	Hopkinsville	Dalton Bros.
Daviess	Moseleyville	Clark Manufacturing Co.
Henderson	Henderson	Kleymeyer-Klutey Brick and Tile Works.
Hopkins	Ashbyburg	Clark Manufacturing Co.
Hopkins	Madisonville	Madisonville Drain Tile Co.
Jefferson	Whitner	Southern Brick & Tile Co.
Madison	Bybee	Walter Cornelison.
Madison	Waco	Waco Pottery.
Marion	Lebanon	Goodwin Brick and Tile Co.
Nelson	New Haven	Nelson Brick & Tile Co.
Union	Uniontown	Alhorn and Waller.
Union	Sturgis	Quinwin Brick & Tile Co.
Webster	Sebree	U. S. Bishop & Sons.
Wolfe	Hazel Green	Hazel Green Brick & Tile Works.

The Fire Brick Industry

The refractories industry of eastern Kentucky is of such importance that it is deserving of special mention.

According to Crider, (Ref. 8), S. Eifort, K. B. Grahn and J. McL. Stoughton bought 10,000 acres of land in the Olive Hill district about 1868, with the intention of erecting an iron furnace. They formed the Tygart Valley Iron Company. The railroad through this region was not built, however, until 1882. The furnace venture apparently was not continued and the three members of the company divided up their land, and later Eifort began to ship fire clay.

In 1871 fire clays were mined in Lewis County and shipped to Cincinnati for making fire brick. It is also claimed by some that in 1870 they were being made at Bellefonte Furnace near Ashland.

Eifort in 1883 shipped the first Olive Hill clay to the Ironton Fire Brick Works, and this gave such good results that soon plants in Ashland, Cincinnati, Sciotoville and Louisville were obtaining clay from there. It will therefroe be seen that much of the clay mined at that time was shipped out of Kentucky.

About this time or in 1884 fire clays were worked at Amanda Furnace, although they may have been worked at a still earlier date.

In 1886 the Ashland Fire Brick Company constructed its plant at Ashland, and this was one of the first plants to be completed in the state.

It was not until 1895, or 5 years later, that Eifort, Grahn plant at Ashland, but this some years later was purchased by the Ashland Fire Brick Company.

It was not until 1895, or 9 years later, that Eifort, Grahn and Stoughton erected a fire brick plant at Olive Hill, and known as the Olive Hill Fire Brick Company. This plant was supplied from the old Burnt House mine which was said to have a deposit of clay is 27 feet thick. From another source we are informed that this plant was built by A. E. Hitchins and Geo. H. Parks. It was subsequently taken over by the General Refractories Company, which has erected a modern plant at the site.

Another early plant established here was the Olive Hill Calcine Company, which was run for the purpose of mining and calcining flint clay. Their mine was a short distance from the Chesapeake and Ohio Railway, up Henderson branch. The enterprise was not very successful, it is said, and the plant was shut down when the clay gave out.

In 1900 the Ashland Fire Brick Company erected its plant at Hayward, Carter County, followed in 1901 by the construction of Harbison-Walker Refractories plant at Olive Hill, and in 1903 by the Kentucky Fire Brick Company at Haldeman.

In 1911 the Louisville Firebrick Works erected a plant at Grahn.

In 1912 the General Refractories Company built its factory at Hitchins.

We thus find a chain of factories extending from Ashland to Haldeman, distributed as follows:

Ashland, 2; Hitchins, 1; Grahn, 2; Olive Hill, 2; Hayward, 1; and Haldeman, 2. These combined plants have an aggregate daily capacity of 445,000 expressed in terms of 9-inch brick. To this might be added the plant of Chas. Taylor & Sons, at McCall, with 40,000 capacity, and the Louisville Fire Brick Works at Highland Park near Louisville, established in 1889, with 50,000 capacity, making a total for the state of 535,000 bricks.

County	Town	Firm Name
Boyd	Ashland	Ashland Fire Brick Co.
Carter	Grahn	Louisville Fire Brick Works.
Carter	Hayward	Ashland Fire Brick Co.
Carter	Hitchins	General Refractories Co.
Carter	Olive Hill	Harbison Walker Refractories Co.
Carter	Olive Hill	General Refractories Co.
Greenup	McCall	Chas. Taylor Sons Co.
Jefferson	Louisville	Louisville Fire Brick Works.
Jefferson	Louisville	P. Bannon Pipe Co.
Rowan	Haldeman	Kentucky Fire Brick Co.

Pottery

More record appears to have been kept of Pottery manufacture in Kentucky than of many other kinds of clay wares. The first establishment noted is that of the Lewis Pottery Com-

pany, started in Louisville in 1829. It, however, only continued until 1836 when the owners were induced to move to Troy, Ind. Again in 1840 another pottery was established by a Mr. Hancock, in Louisville. In the Geological Survey Report for 1856 a Calloway County clay is said to have been used by Captain Bonner in that county for making stoneware. This material was possibly some of the Tertiary clay of that region which has since become important for use in pottery and tile manufacture.

Pottery works were started at Paducah in 1886, but the clays employed came from Grand Chain, Ill., Boaz, Ky., and Round Knob, Ill.

By the year 1888, potteries making brown jars and jugs were in operation at Pottertown, Bell City, Lynnville, Paducah, Columbus and Hickman, but they were small plants built to supply local trade, and all located in the Purchase region. Some of them are no longer in operation. As late as 1906 potteries were in operation at Paducah, Pottertown, Rock, Tompkinsville, Wickliffe, Water Valley, Mayfield and Columbus in the Purchase area, but only at the first named locality is one still in operation.

Crider (Ref. 8, p. 675) describes a pottery plant located near Cliffside Park, between Ashland and Catlettsburg, which was still in operation in 1912, but is so no longer. It made stoneware jugs, etc.

At the present day there are few potteries in operation within the state, although there exists an abundance of raw materials suitable for common earthenware and stoneware manufacture. The New Providence shale supplies an excellent clay for making red flower pots, while stoneware clays can be obtained either from the Tertiary formations of the Purchase region or from those of Madison County.

The following list gives the potteries at present operating in Kentucky together with the class of ware produced:

County	Town	Firm Name	Product
Calloway	Pottertown	Falwell and Son	Stoneware.
Graves	Bell City	W. D. Russell	Stoneware.
Jefferson	Louisville	Louisville Pottery Co.	Stoneware, Red Earthenware, Imitation whiteware.

County	Town	Firm Name	
McCracken	Paducah	Paducah Pottery Co.	Stoneware.
Madison	Bybee	Bybee Pottery Co.	Hand made blue art pottery.
Madison	Waco	Waco Pottery	Stoneware and blue art pottery.

Clay Mining Industry

The clay mining industry is developed in three areas, viz.: 1. The Purchase region. 2. Around Covington; and 3, the Olive Hill region.

The clays dug in the Purchase region are nearly all obtained from the Lagrange formation, and are worked in Graves County. They are refractory clays, often of high plasticity, and good bonding power. Many of them burn sufficiently white to be used in whiteware bodies. They are consequently employed in mixtures for white earthenware, electrical porcelain, sanitary ware, wall and floor tile, glass refractories, graphite crucibles, saggers, etc.

Those which are dug near Briensburg in the Purchase region are used in stoneware.

The clays that are dug around Covington are not refractory, but are used locally at founderies and iron furnaces.

The clays obtained in the Olive Hill district bear a wide and excellent reputation for the maintenance of refractories. Some of the mines are operated by the companies using the clay, while others are worked by companies or individuals who have no brick plants, but sell the clay to the consumer.

Not a little of the fire clay therefore finds its way to plants located in Ohio, notably those at Portsmouth, Cincinnati and Ironton. The balance is used chiefly at fire brick plants located in the eastern coalfield, though some is shipped to Louisville.

The following is a list of clay miners, who do not own clay-manufacturing plants, or whose mines are not adjacent to factory:

County	Town	Firm Name
Ballard	Wickliffe	American Clay Co.
Ballard	Wickliffe	La Clede Christy Clay Co.
Calloway	Murray	U. S. Clay Co. (Not developed.)
Calloway	Murray	Calloway County Clay Co. (Not developed.)

County	Town	Firm Name
Carter	Aden	Kerns Mining Co.
Carter	Denton	J. H. Burdette.
Carter	Denton	Harbison-Walker Refractories Co.
Carter	Soldier	J. D. Patton.
Carter	Soldier	P. Bannon Pipe Co.
Carter	Soldier	Harbison-Walker Refractories Co.
Graves	Hickory	Excelsior Ball Clay Co.
Graves	Hickory	Colonial Clay Co.
Graves	Hickory	Old Hickory Clay & Talc Co.
Graves	Hickory	M. B. Cooley Clay Co.
Graves	Hickory	West Kentucky Clay Co.
Graves	Viola	Kentucky Clay Mining Co.
Graves	Pryorsburg	Kentucky Construction and Improvement Co.
Graves	Pryorsburg	Mayfield Clay Co. (Not operating.)
Kenton	Covington	S. J. Moore.
Marshall	Benton	Howard Clay Pit. (Not operating)
Marshall	Benton	Lon Lofton Clay Pit. (Not operating.)
Marshall	Briensburg	Paducah Clay Co.
Rowan	Gates	Gilmore Fire Clay Co.
Rowan	Morehead	General Refractories Company.
Rowan	Enterprise	Ironton Fire Brick Co.

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WILLARD ROUSE JILLSON, DIRECTOR AND STATE GEOLOGIST

SERIES VI. 1922

GEOGRAPHIC MAP OF KENTUCKY

SHOWING DISTRIBUTION OF

CLAY INDUSTRIES AND OUTLINE OF SEPARATE AREAS TREATED IN THE REPORT ON

THE CLAYS AND CLAY INDUSTRIES OF KENTUCKY

BY H. RIES

Scale

LEGEND

- Hollow blocks
- Fire brick
- Brick
- Drain tile
- Sewer pipe
- Floor and Wall tile
- Roofing tile
- Pottery
- Clay mines

CHAPTER II

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CHAPTER VI

GENERAL SECTION FROM MISSISSIPPI RIVER TO BIG SANDY RIVER

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